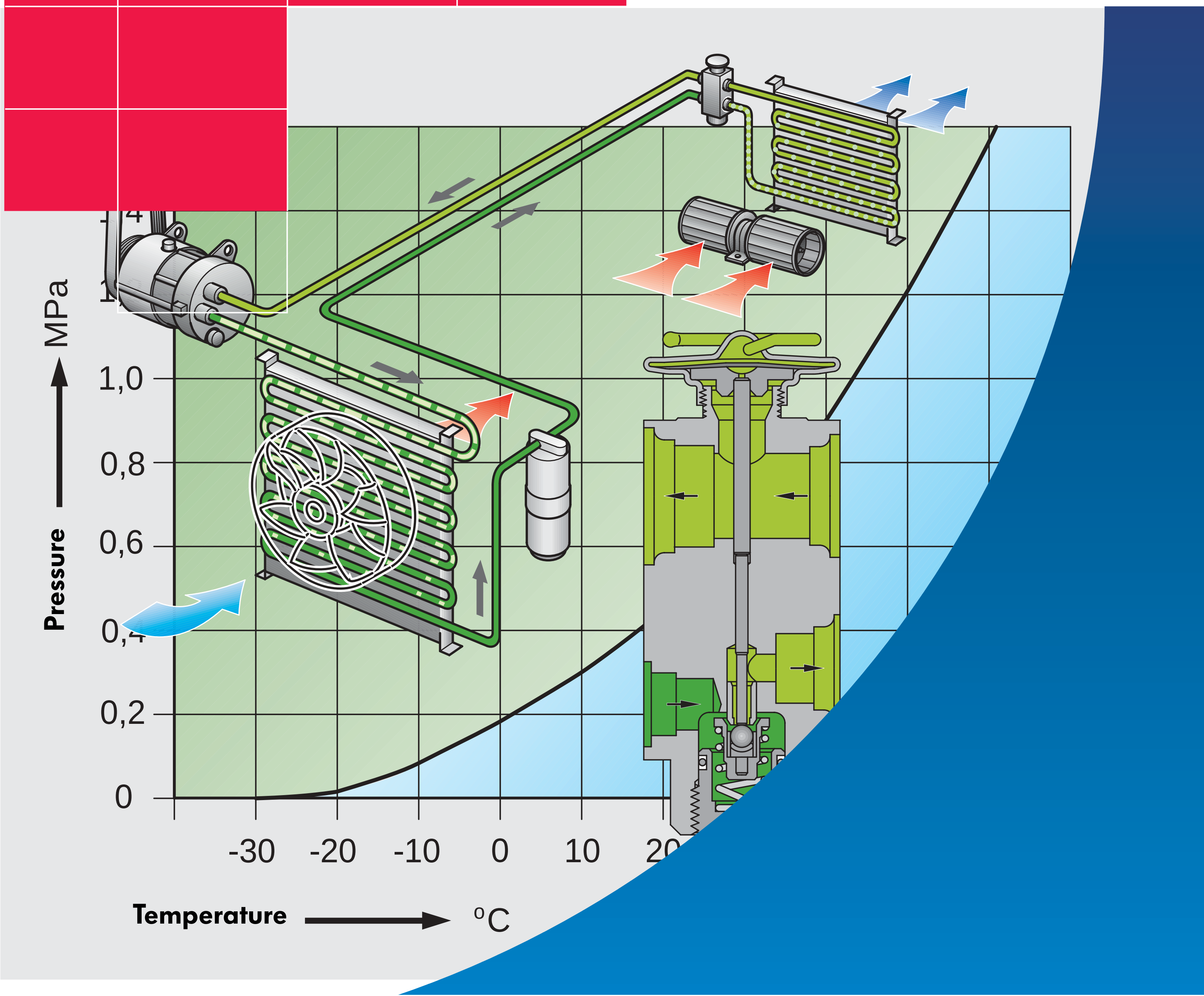
208

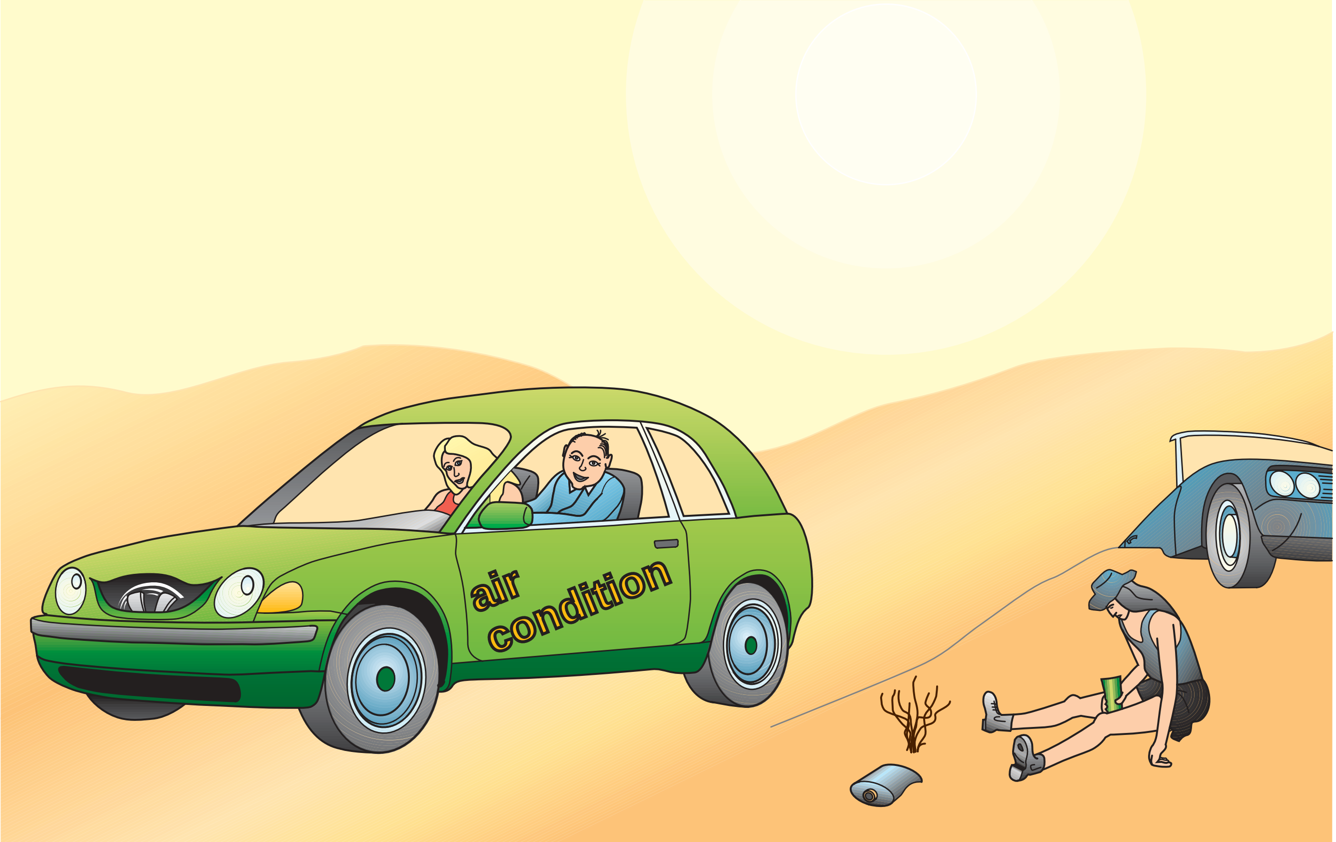
Service.

Self-Study Programme 208

Air Conditioner in the Motor Vehicle

Fundamentals





Air conditioning systems have long ceased to be regarded as luxury equipment.
Air conditioners have become a factor in active safety, and today can almost be considered as an integral part of a vehicle's safety specification.

10 years ago, only about 10 percent of all newly registered vehicles were fitted with an air conditioning system. By 1996, air conditioners were being installed as standard in more than one in four newly registered vehicles.

Customer demand for air conditioning is rising continually.

The design of the refrigerant circuit of an air conditioner is identical in all vehicles.
Air conditioner refrigerant circuits only vary in respect of how they are adapted to meet refrigeration requirements.

In this Self-Study Programme, you will familiarise yourself with the basic purpose and design of an air conditioner.
You will learn the functions of the component parts in the refrigeration process, the special characteristics of the refrigerant and why air conditioners require special service specifications.

The component parts shown in the following SSP are common to most air conditioners.

Please note that the figures specified are given by way of example only.
Depending on refrigeration requirements, the absolute values vary from vehicle to vehicle.

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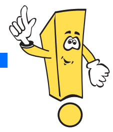

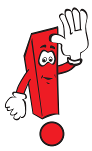
Important Note

The Self-Study Programme is not a Workshop Manual!

Please always refer to the relevant Service Literature for all inspection, adjustment and repair instructions.
Service literature.

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The in-car climate

Why air conditioning?

People feel comfortable at a certain ambient temperature and atmospheric humidity.

As a component part of active safety, the driver's well-being is a key factor in driving ability.

The “in-car climate“ has a direct bearing on the driver, fatigue-free driving and driving safety.

A comfortable interior temperature is dependent upon the prevailing ambient temperature and upon sufficient air flow:

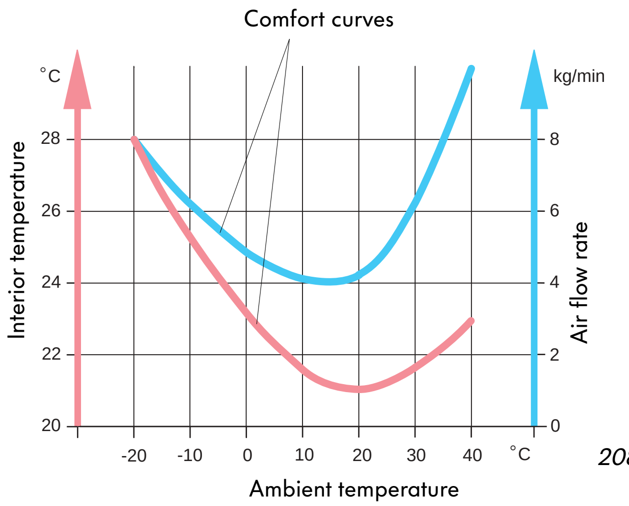
Low ambient temperature, e.g. –20 °C
➡ Higher interior temperature 28 °C
High air flow rate: 8 kg per min.

High ambient temperature, e.g. 40 °C
➡ Low interior temperature 23 °C
High air flow rate: 10 kg per min.

Moderate ambient temperature, e.g. 10 °C
➡ Low interior temperature 21.5 °C
Low air flow rate: 4 kg per min.

Even modern heating and ventilation systems have difficulty maintaining a pleasant climate inside a vehicle at high ambient temperatures.
Why?

– In strong sunlight in particular, the heated cabin air can only be exchanged for air with ambient temperature.
– In addition, the air temperature usually rises en route from the intake point to the air outlet.
– Opening a window or sliding roof or setting a higher fan speed for greater comfort will usually result in a draught and expose the occupants to other nuisances such as noise, exhaust gases and pollen.



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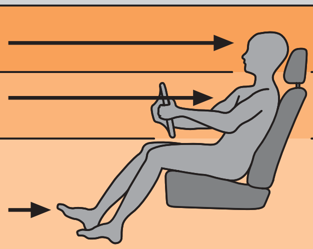
High levels of atmospheric humidity put the body under considerably greater physical strain.

Temperatures in a mid-range passenger car
where: driving time 1 h
ambient temperature 30°C
sunlight penetration into car

Area	with air conditioning	without air conditioning
Head	23 °C	42 °C
Chest	24 °C	40 °C
Feet	28 °C	35 °C



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Effects of an unfavourable vehicle interior temperature on humans

Scientific studies conducted by the WHO (World Health Organization) have shown that one's ability to concentrate and reactions are impaired when under stress.

Heat puts a strain on the body.

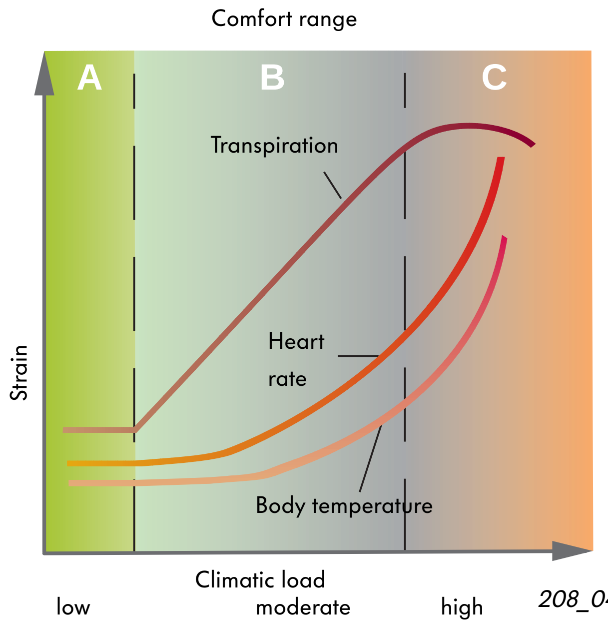
The best temperature for the driver is between 20 and 22 °C.
This is equivalent to climatic load A, the "comfort range".

Strong sunlight can increase the interior temperature by more than 15 °C above the ambient temperature– particularly in the head area.
This is where the effects of heat are most dangerous.

The body temperature rises and the heart rate increases.
Heavier perspiration will typically occur, too.
The brain is not receiving enough oxygen.
Also refer to "climatic load range B".

Climatic loads in range C put an excessive strain on the body.
Physicians specialising in traffic-related illnesses refer to this condition as “climatic stress“.

Studies have shown that an increase in temperature from 25 to 35 °C reduces one's sensory perception and powers of reasoning by 20%. It has been estimated that this figure is equivalent to a blood alcohol concentration of 0.5 millilitres alcohol level.



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The air conditioner - a system which keeps the air temperature at a level comfortable to humans, as well as purifying and dehumidifying the air -– was created in order to reduce or eliminate completely such stress.

With the help of an air conditioner it is possible to produce at the air outlets a temperature which is much lower than high outside air temperatures.
This is possible both when the vehicle is at a standstill and when it is in operation.

A technical side-effect of air conditioning is that the air is dehumidified and cleaned at the same time. However, this is just as important as the reduction in temperature.
The pollen filter and activated charcoal filter also help to clean the air entering the vehicle.
People with allergic illnesses benefit greatly from being able to breathe clean air.

In-vehicle air conditioning is

- a real safety element

- a functional accessory not only for expensive tastes

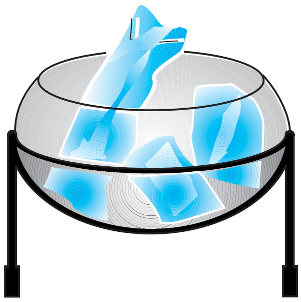
Physics of the cooling system

Applied physics

Laws

Many substances are known to exist in three aggregate states.

Take water for example: solid – liquid – vapour.
The principle of cooling follows this law.



Ice – solid

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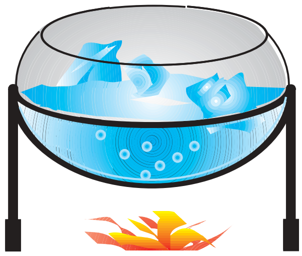
Even in ancient times there was a need for cooling. One of the first methods used to cool foodstuffs was to store them in an “icebox“.

The ice (water in a solid aggregate state) absorbs the heat of the foodstuffs, thereby cooling them down.



Ice – becomes a liquid when it absorbs heat

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The ice melts as a result, assuming another aggregate state, namely that of a liquid (water).

If the water is heated further, it will boil and evaporate.
The water is now in the gaseous state.

Water – becomes a gas when it absorbs heat

208_041

The gaseous substance can be converted back to a liquid by cooling it and will become a solid again if cooled further.
This principle is applicable to almost all substances:

- A substance absorbs heat when it is converted from a liquid to a gas.
- A substance gives off heat when it is converted from a gas to a liquid.
- Heat always flows from the warmer substance to the colder substance.

Law

Air conditioners utilise the effects of heat exchange, a process in which a substance changes state at certain points.

Freezing point,
e.g. water becomes ice,
Boiling point
e.g. water becomes steam

Pressure and boiling point

If the pressure is changed using a liquid, the boiling point changes.
All liquids behave similarly.

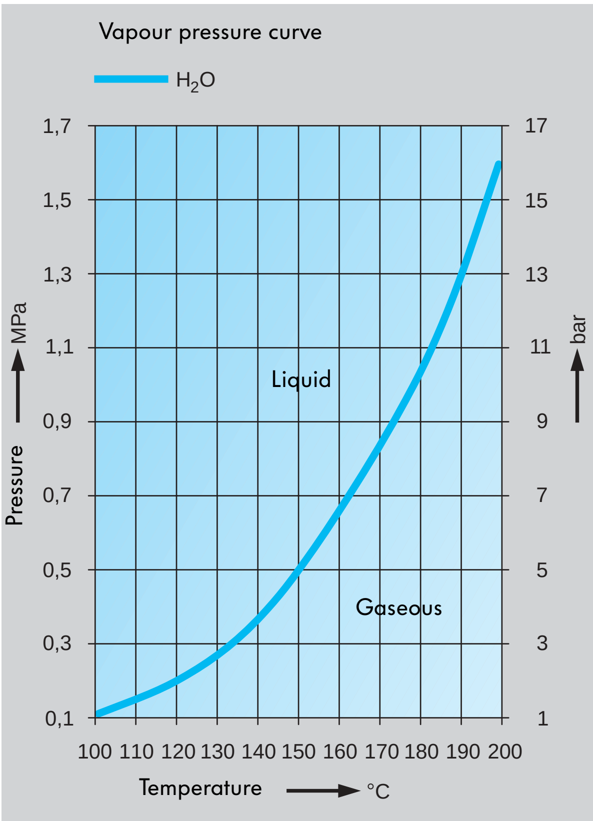
Boiling point	H_2O/water	=	100 °C
	Machine oil	=	380 - 400 °C

The lower the pressure, the lower the temperature at which water boils (evaporates).

The evaporation process is also used in vehicle air conditioners.
A substance with a low boiling point is used for this purpose.
This substance is known as a refrigerant.

Boiling point	Refrigerant R12	–29.8 °C
	Refrigerant R134a	–26.5 °C

(The boiling points specified for liquids in the table always refer to an atmospheric pressure of 0.1 MPa = 1 bar.)



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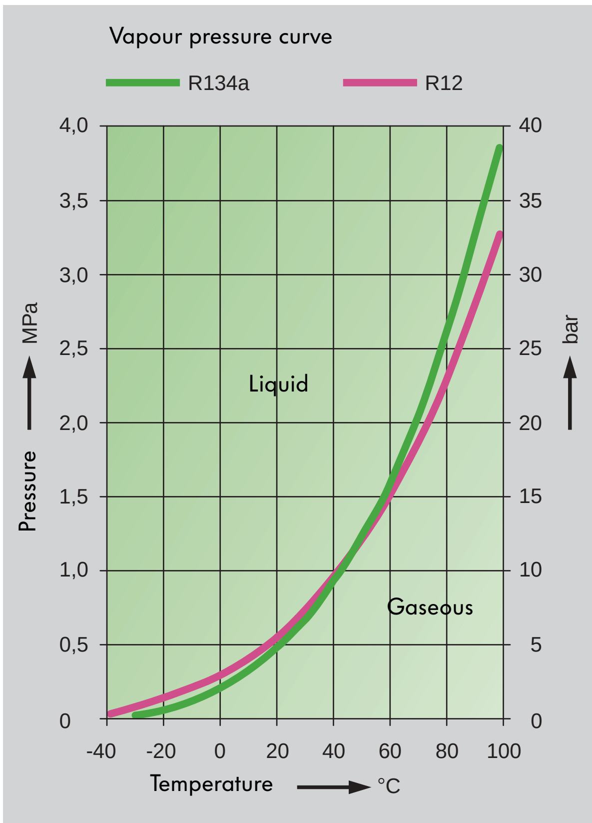

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What does a vapour pressure curve tell us?

We can draw the following conclusions from the vapour pressure curve for the two refrigerants R134a and R12 (R12 is no longer used) and water:

- **At a constant pressure, the vapours become a liquid through temperature reduction (in the air conditioner circuit, this process takes place in the condenser = liquefier),**
- **The refrigerant goes from a liquid state to a vapour state through pressure reduction (in the air conditioner circuit, this process takes place in the evaporator).**

The refrigerant

R 134a

The refrigerant with a low boiling point used for vehicle air conditioners is a gas.

As a gas, it is invisible.
As a vapour and as a liquid, it is colourless like water.

Refrigerants may not be combined with each other. Only the refrigerant specified for the system in question may be used.

Refrigerant **R12** – Dichlordifluormethane
chem. formula CCl_2F_2

a chlorinated hydrocarbon (**CFC**)
harmful to the environment!

Refrigerant **R134a** – Tetrafluorethane
chem. formula $CH_2F\text{-}CF_3$

a fluorocarbon (**FC**)
environmentally friendly!

With regard to vehicle air conditioners, the sale and filling of refrigerant R12 were banned in Germany with effect from 1995 and July 1998 respectively.

In current automotive air conditioners, only refrigerant R134a is used.

- R134a – a fluorocarbon contains no chlorine atoms - unlike refrigerant R12 - which cause depletion of the ozone layer in the earth's atmosphere when they split.
- The vapour pressure curves of R134a and R12 are very similar.
  R134a has the same refrigeration capacity as R12.

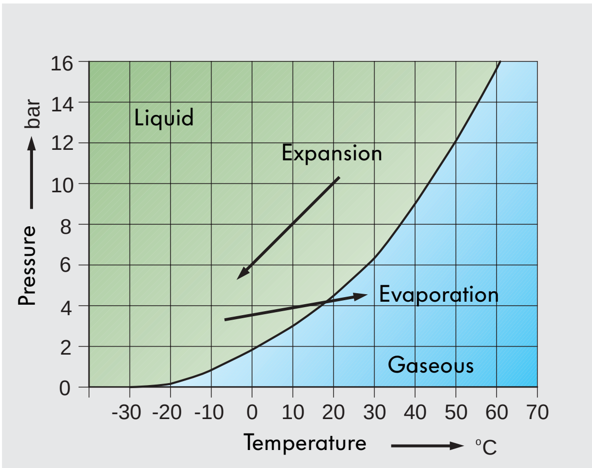
  It is possible to adapt air conditioners which now may no longer be filled with R12 to R134a with a special conversion kit (Retrofit method).

  The systems converted in this way are no longer able to match their original refrigeration capacity.

Ordinance banning halogens

R134a

Depending on the pressure and temperature conditions in the refrigerant circuit, the refrigerant will either be a gas or a liquid.



Vapour pressure curve of R134a

208_050

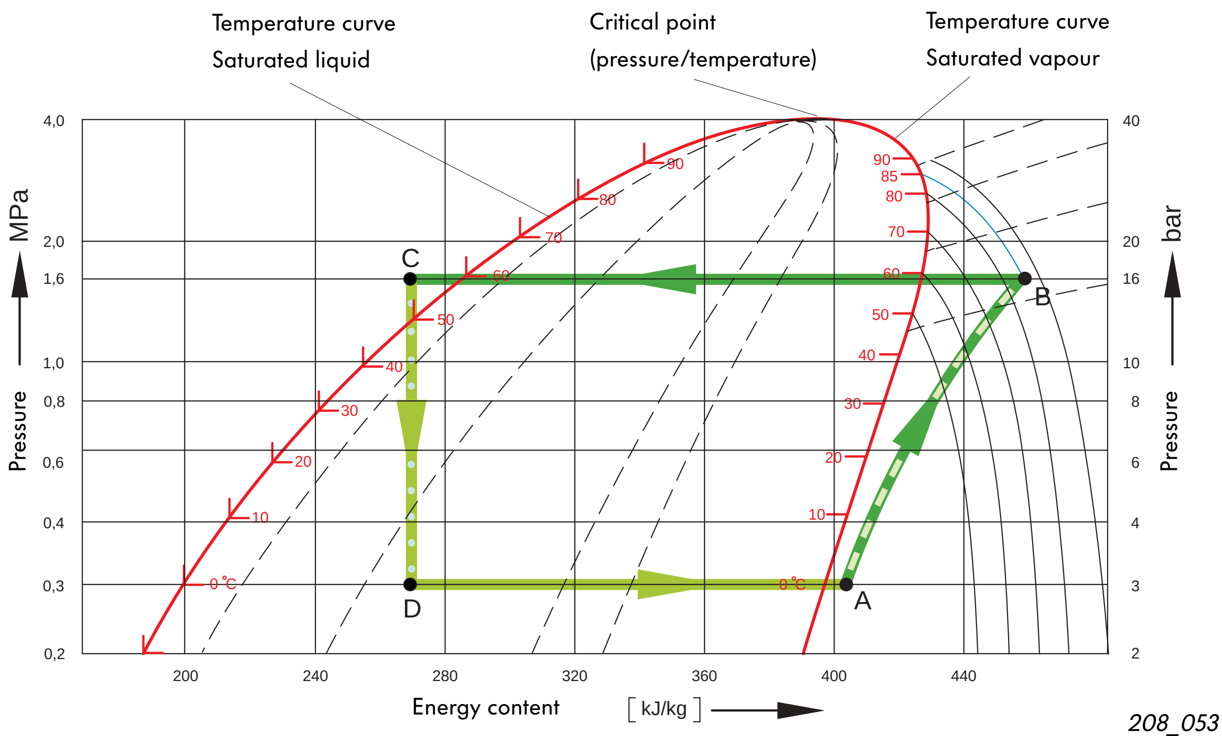
State of refrigerant R134a in the cycle in an air conditioner

In addition to the vapour pressure curve, the cycle shows the change of state of the refrigerant under pressure and temperature in addition to the energy balance at which the refrigerant returns to its original state.
The diagram is an excerpt from the state diagram of refrigerant R134a for a vehicle air conditioner.
Different absolute values are possible in dependence upon the demand of a vehicle type for refrigeration capacity.

The energy content is a key factor in the design of an air conditioner.
It shows what energy is required (evaporator heat, condenser heat) to achieve the intended refrigeration capacity.

Physical data of R134a:

Boiling point:	–26.5 °C
Freezing point:	–101.6 °C
Critical temperature:	100.6 °C
Critical pressure:	4.056 MPa
	(40.56 bar)



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A – B Compression in the compressor, pressure and temperature rise, gaseous, high pressure, high temperature

B – C Condensation process in the condenser, high pressure, temperature reduction, the liquid leaves the condenser slightly cooled

C – D Expansion = sudden pressure relief, results in evaporation

D – A Evaporation process (heat absorption) in the evaporator. Transition path from vapour state to gaseous state (low pressure)

Temperature curve at point B

For a glossary refer to page 72.

The refrigerant

R 134a

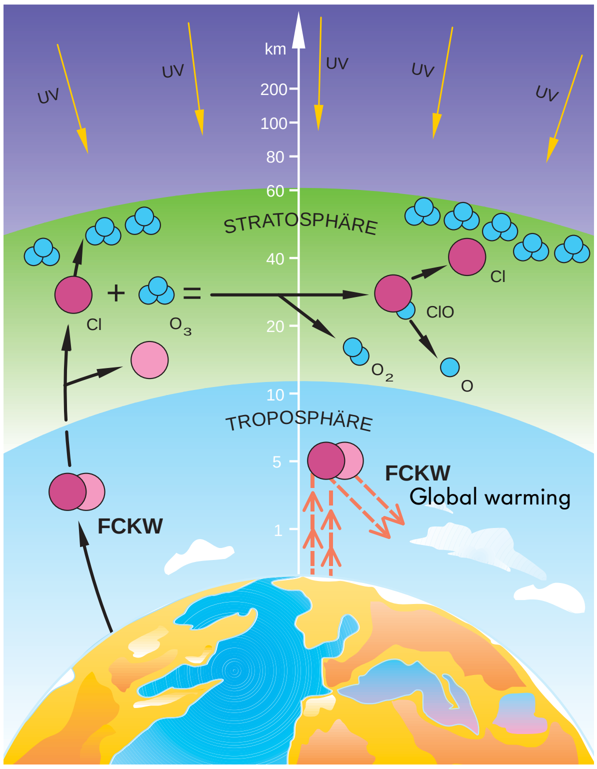
Refrigerants and ozone layer

Ozone protects the earth's surface against UV radiation by absorbing a large proportion of these rays.
UV rays split ozone (O_3) into an oxygen molecule (O_2) and in an oxygen atom (O).
Oxygen atoms and oxygen molecules from other reactions combine again to form ozone.
This process takes place in the ozonosphere, a part of the stratosphere at an altitude of between 20 and 50 km.

Like R12, chlorine (Cl) is a constituent of a CFC refrigerant .
If handled improperly, the R12 molecule will rise up to the ozone layer– since it is lighter than air–.

UV radiation liberates a chlorine atom in the CFC, and this atom reacts with the ozone.
In the process, the ozone decomposes leaving an oxygen molecule (O_2) and chlorine monoxide (ClO), which then reacts again with oxygen and liberates chlorine (Cl). This cycle can repeat itself as many as 100,000 times.

However, free oxygen molecules (O2) cannot absorb UV radiation.



208_051

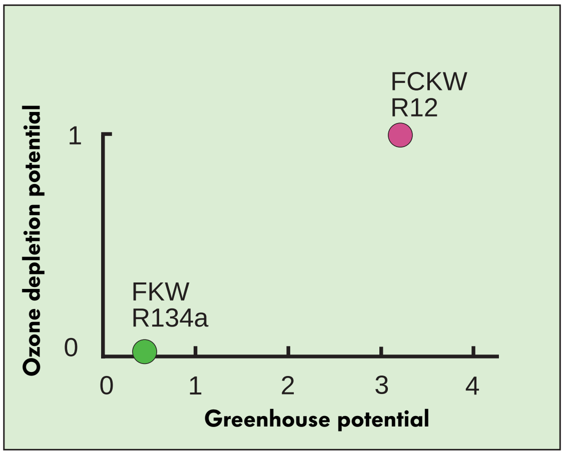
Reaction between CFC and ozone in the atmosphere (CFC = FCKW)

Refrigerants and global warming

The sunlight impinging upon the earth's surface is reflected in the form of infrared radiation.
However, trace gases – most importantly CO_2 – reflect these waves in the troposphere.
This causes the earth's atmosphere to heat up,– a phenomenon which is commonly referred to as "global warming". CFCs are heavily responsible for the increasing trace gas concentration.

1 kg of R12 has the same greenhouse effect as 4000 tons of CO_2.

R134a only makes a small contribution to global warming.
Its ozone depletion potential is nil.



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R
134a

Refrigerant oil

A special oil – the refrigerant oil – free of impurities such as sulphur, wax and moisture is required to lubricate all the movable parts in the air conditioner.

The refrigerant oil must be compatible with the refrigerant itself, because some of the refrigerant oil mixes with the refrigerant in the refrigerant circuit. In addition, the refrigerant oil must not attack the seals used in the system.

No other oils may be used, as they lead to copper plating, the build-up of carbon deposits and the formation of residues which can cause premature wear and irreparable damage to movable parts.

A special synthetic oil is used for the R134a refrigerant circuit. This oil may only be used for this particular refrigerant, since it does not mix with other refrigerants.

Also, the refrigerant oil can only be adapted to a specific compressor type.

The refrigerant for R134a

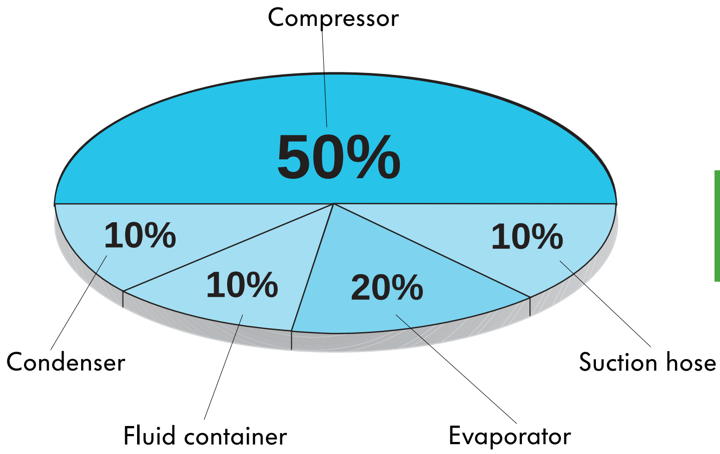
Designation: **PAG** = Polyalkylene glycol

Properties:

- high solubility in combination with refrigerant
- good lubrication properties
- acid free
- highly hygroscopic (water-attracting)
- cannot be mixed with other oils

N.B.:

- must not in be used in older refrigeration systems
  filled with refrigerant R12,
  since it is incompatible with R12



Distribution of oil quantity in the refrigerant circuit (roughly)
The filling quantity of refrigerant varies according to the design of the units used in a particular type of vehicle.

Important notes:

– Do not store in the open (highly hygroscopic).
– Always keep oil tanks closed to protect them against the ingress of moisture. Close opened drums immediately.
– Do not use old refrigerant.
– **Dispose of as toxic waste.**
Refrigerant may not be disposed of together with engine oil or gear oil because of its chemical properties.

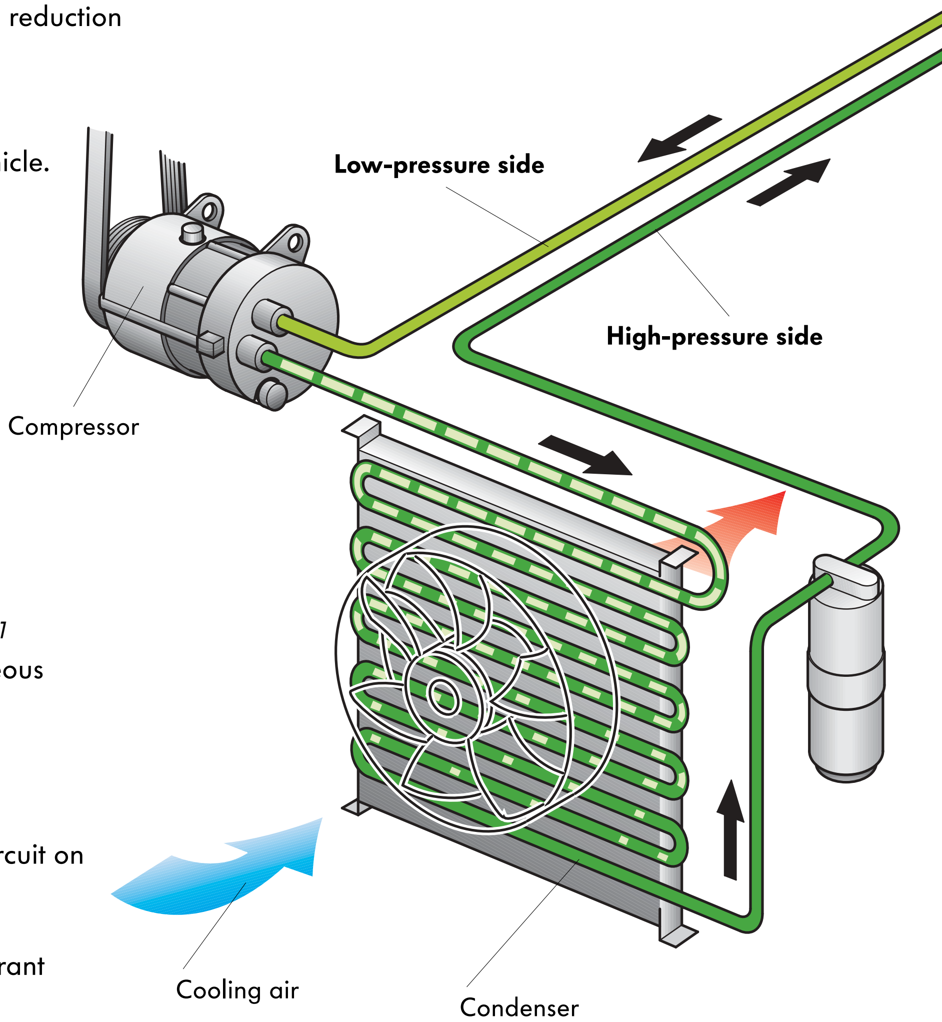
The principle of the refrigerant circuit

The cooling process and the technical conditi-ons

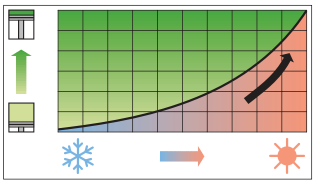
We know that:
Too cool down an object, heat must be given off. A compression refrigeration system is used in motor vehicles for this purpose. A refrigerant circulates in the closed circuit, continually alternating changing from a liquid to a gas and vice versa. The refrigerant is:

- compressed in the gaseous state,
- condensed through heat dissipation
- and evaporated through pressure reduction and heat absorption.

Cool air is not produced, heat is extracted from the air flow in the vehicle.



How does this process work?



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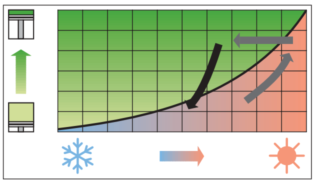
The **compressor** induces cold, gaseous refrigerant at a low pressure.

The refrigerant is compressed in the compressor, causing it to heat up.
The refrigerant is pumped into the circuit on the high-pressure side.

In this phase, the refrigerant is in a gaseous state, has a high pressure and a high temperature.



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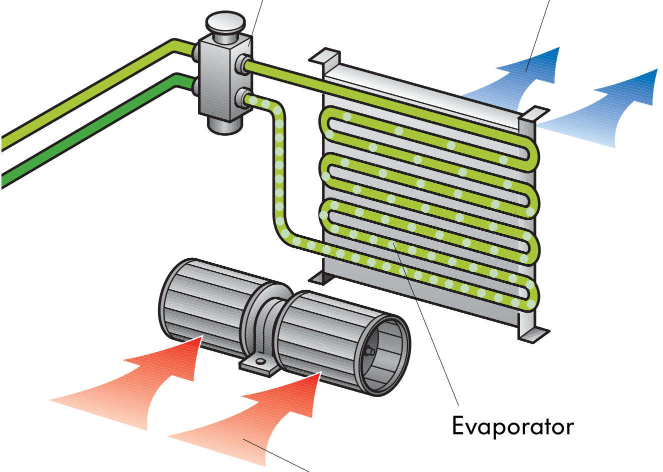
The compressed liquid refrigerant continues to flow up to a narrowing. This narrowing can be in the form of a restrictor or an expansion valve.
Once the refrigerant reaches the narrowing, it is injected into the evaporator causing its pressure to drop (low-pressure side).



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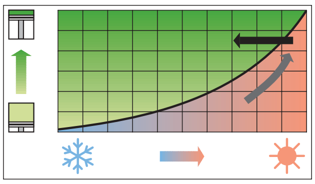
Inside the **evaporator**, the injected liquid refrigerant expands and evaporates. The evaporation heat required for this purpose is extracted from warm fresh air which cools down when it passes through the evaporator fins.
The temperature inside the vehicle is reduced to a pleasant level.

In this phase, the refrigerant
is in a vapour state,
under low pressure and
at low temperature.



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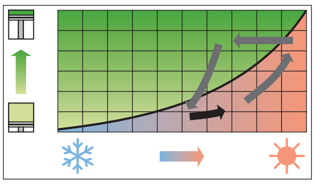
The refrigerant follows the short path to the **condenser** (liquefier).
Heat is now extracted from the compressed, hot gas in the condenser by the air flowing through (headwind and fresh air blower).
The refrigerant condenses and becomes a liquid when it reaches its melting point (pressure-dependent).

In this phase, the refrigerant
is therefore
in a liquid state,
has a high pressure
and a medium temperature.



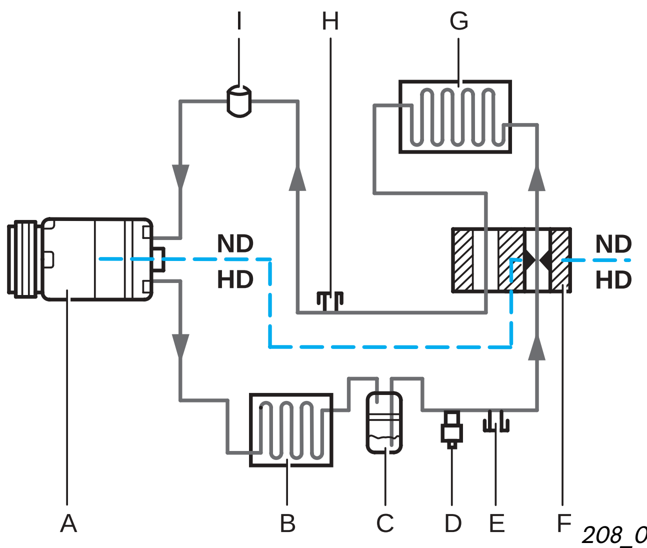
208_074

Now in the gaseous state again, the refrigerant emerges from the evaporator.
The refrigerant is again drawn in by the compressor and passes through the cycle once again.
Thus, the circuit is closed.

In this phase, the refrigerant
is again
gaseous,
has a low pressure
and a low temperature.

The cooling system

Refrigerant circuit with expansion valve



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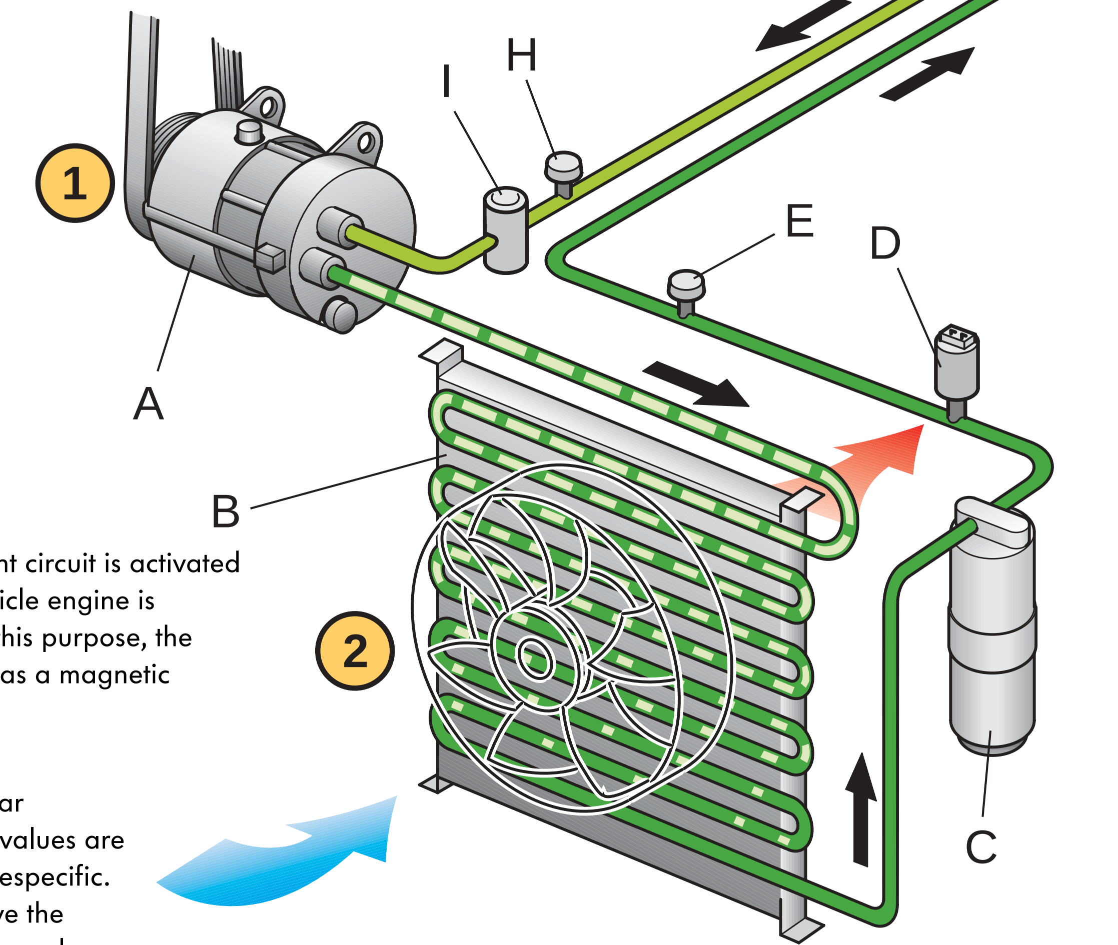
Working pressure HD = High-pressure
ND = Low pressure

In technical documents such as Workshop Manuals, the components are represented in a diagrammatic form.



The refrigerant circuit is activated when the vehicle engine is running. For this purpose, the compressor has a magnetic clutch.

1 MPa = 10 bar
The absolute values are always vehiclespecific. Please observe the Workshop Manual.

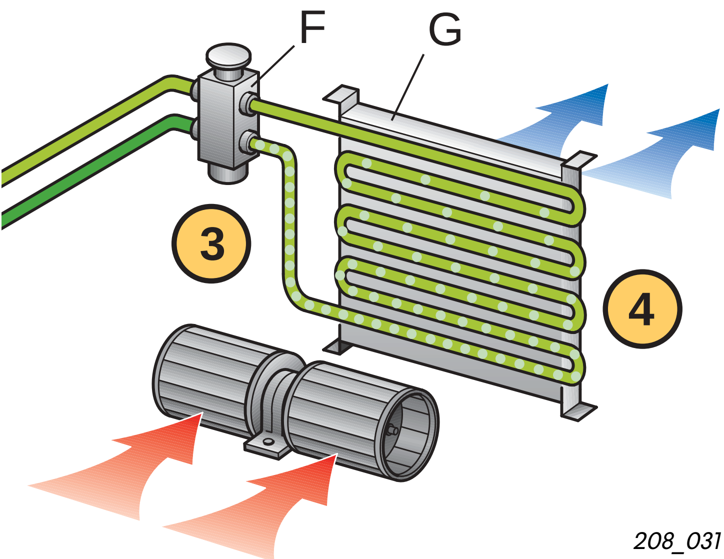
Pressures and temperature in the circuit (example)

1 **Compression ratio**
at approx. 1.4 MPa (14 bar)
Temperature approx. 65 °C

2 **Condensation**
Pressure approx. 1.4 MPa (14 bar)
Temperature reduction: 10 °C

Legend

- High pressure
- Low pressure



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The components:

A Compressor with magnetic clutch
B Condenser
C Fluid container with drier
D High-pressure switch
E High-pressure service connection
F Expansion valve
G Evaporator
H Low-pressure service connection
I Damper (vehicle-specific)

The refrigerant circuit may not be opened for safety reasons.
If it is necessary to open the refrigerant circuit in order to perform repair work on the vehicle, the refrigerant must be drawn off beforehand using a suitable service station.

The refrigeration capacity of a vehicle air conditioner is dependent upon the car-specific installation conditions and the vehicle category (passenger cars, vans).

The components A to H exist in every circuit. Additional connections can be provided for service work, temperature sensors, pressure switches in the high- and low-pressure circuit and oil drain screws depending on the circuit design and requirements. The layout of components within the circuit also differs from one vehicle type to another.
Some systems have a damper before the compressor in order to dampen refrigerant vibrations.

The pressures and temperatures in the circuit are always dependent on momentary operating state. The specified values are intended as a rough guideline only. They are reached after 20 min. at an ambient temperature of 20 °C and at engine speeds of between 1500 and 2000 rpm.

At 20 °C and when the engine is at a standstill, a pressure of 0.47 MPa (4.7 bar) will build up inside the refrigerant circuit.

The components of the refrigerant circuit with expansion valve will now be examined more closely (for details of the refrigerant circuit with restrictor refer to page 28).

Expansion
from approx. 1.4 MPa (14 bar) to approx. 0.12 MPa (1.2 bar), Temperature: from approx. 55 °C to –7 °C

Evaporation
Pressure: approx. 0.12 MPa (1.2 bar)
Temperature: approx. –7 °C

208_033

The cooling system

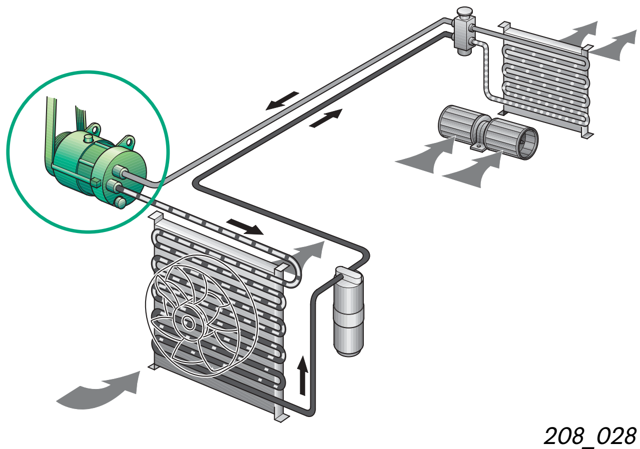
The compressor

The compressors used in vehicle air conditioners are oil-lubricated displacement compressors. They operate only when the air conditioner is switched on, and this is controlled by means of a magnetic clutch.

The compressor increases the pressure of the refrigerant. The temperature of the refrigerant rises at the same time.

Were there to be no pressure increase, it would not be possible for the refrigerant in the air conditioner to expand and therefore cool down subsequently.

A special refrigerant oil is used for lubricating the compressor. About half of it remains in the compressor while the other half is circulated with the refrigerant.
A pressure shut-off valve, which is usually attached to the compressor, protects the system against excessively high pressures.



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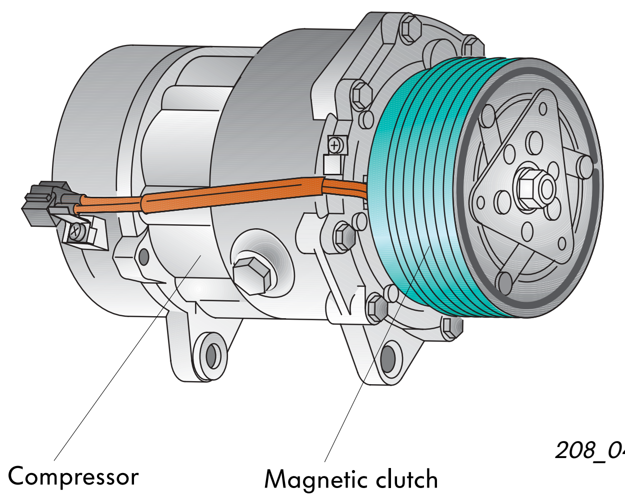
The compression process

The compressor draws in cold, gaseous refrigerant through the evaporator under low pressure .

It is "vital" for the compressor that the refrigerant be in a gaseous state, because liquid refrigerant cannot be compressed and would destroy the compressor (in much the same way as a water shock can damage an engine).

The compressor compresses the refrigerant and forces it towards the condenser as a hot gas on the high-pressure side of refrigerant circuit.

The compressor therefore represents the interface between the low-pressure and high-pressure sides of the refrigerant circuit.



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Mode of operation of compressor

Compressors for air conditioners operate according to various principles:

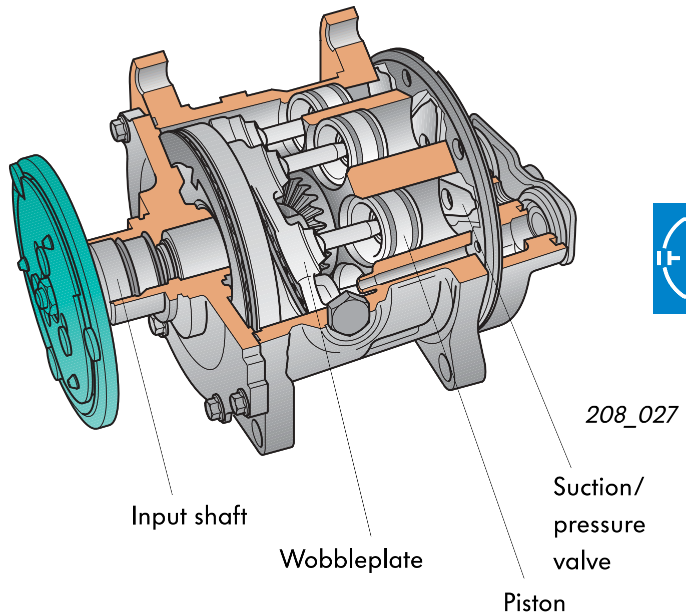
- Reciprocating compressors
- Coiled tube compressors
- Vane-cell compressors
- Wobbleplate compressors

Wobbleplate compressors will now be examined in more detail.

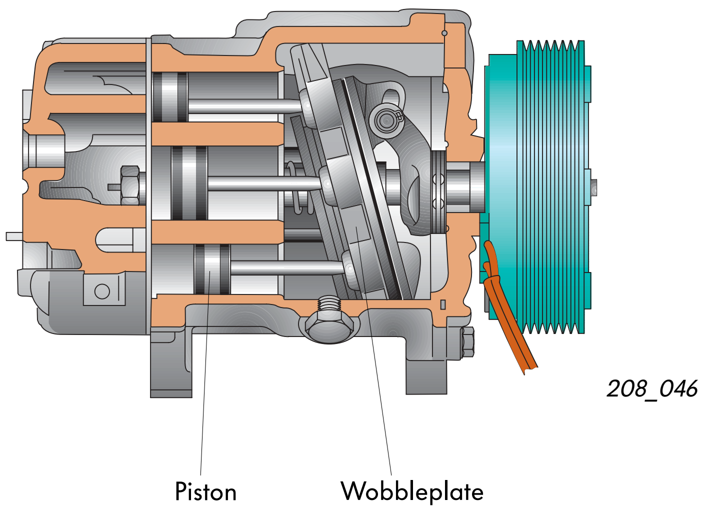
The turning motion of the input shaft is converted to an axial motion (= piston stroke) by means of the wobbleplate.
Depending on compressor type, between 3 and 10 pistons can be centred around the input shaft.
A suction/pressure valve is assigned to each piston.
These valves open/close automatically in rhythm with the working stroke.
An air conditioner is rated for the max. speed of the compressor.
However, the compressor output is dependent on engine rpm.
Compressor rpm differences of between 0 and 6000 rpm can occur.
This affects evaporator filling as well as the cooling capacity of the air conditioner.
Controlled-output compressors with a variable displacement were developed in order to adapt compressor output to different engine speeds, ambient temperatures or driver-selected interior temperatures.

Compressor output is adapted by adjusting the angle of the wobbleplate.

In constant-displacement compressors, compressor output is adapted to the demand for refrigeration by switching the compressor on and off periodically via the magnetic clutch.



Wobbleplate compressor (non-self-regulating)
Angle of wobbleplate constant
Displacement constant

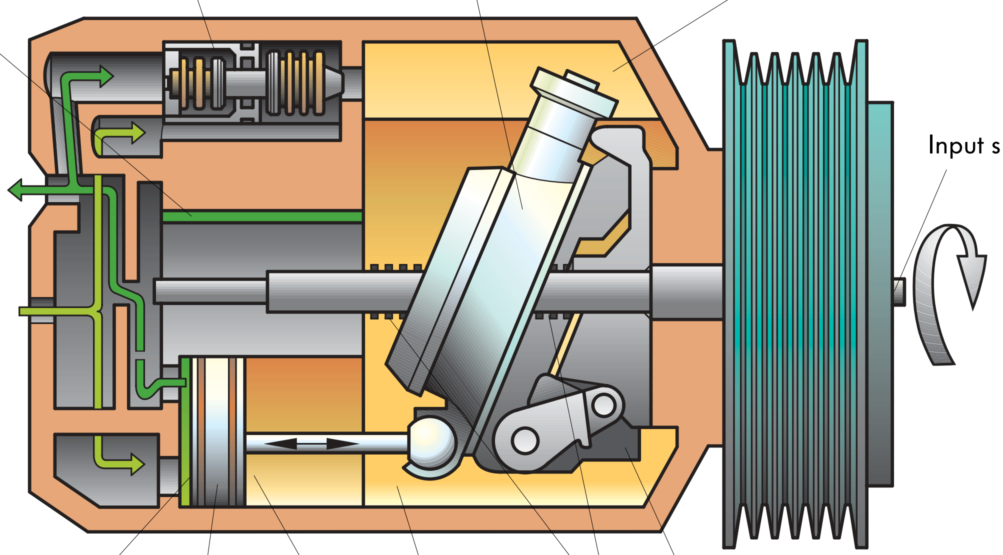


Wobbleplate compressor (self-regulating)
Angle of wobbleplate variable
Displacement variable

The self-regulating compressor runs continously in air condition mode

Control range of compressor

➡ All control positions between upper stop (100 %) and the lower stop (approx. 5 %) are adapted to the required delivery rate by altering the chamber pressure.
The compressor is on continuous duty during the control cycle!



208_047

The turning motion of the input shaft is transmitted to the drive hub and converted to axial motion of the piston via the wobbleplate. The wobbleplate is located longitudinally in a slide rail.

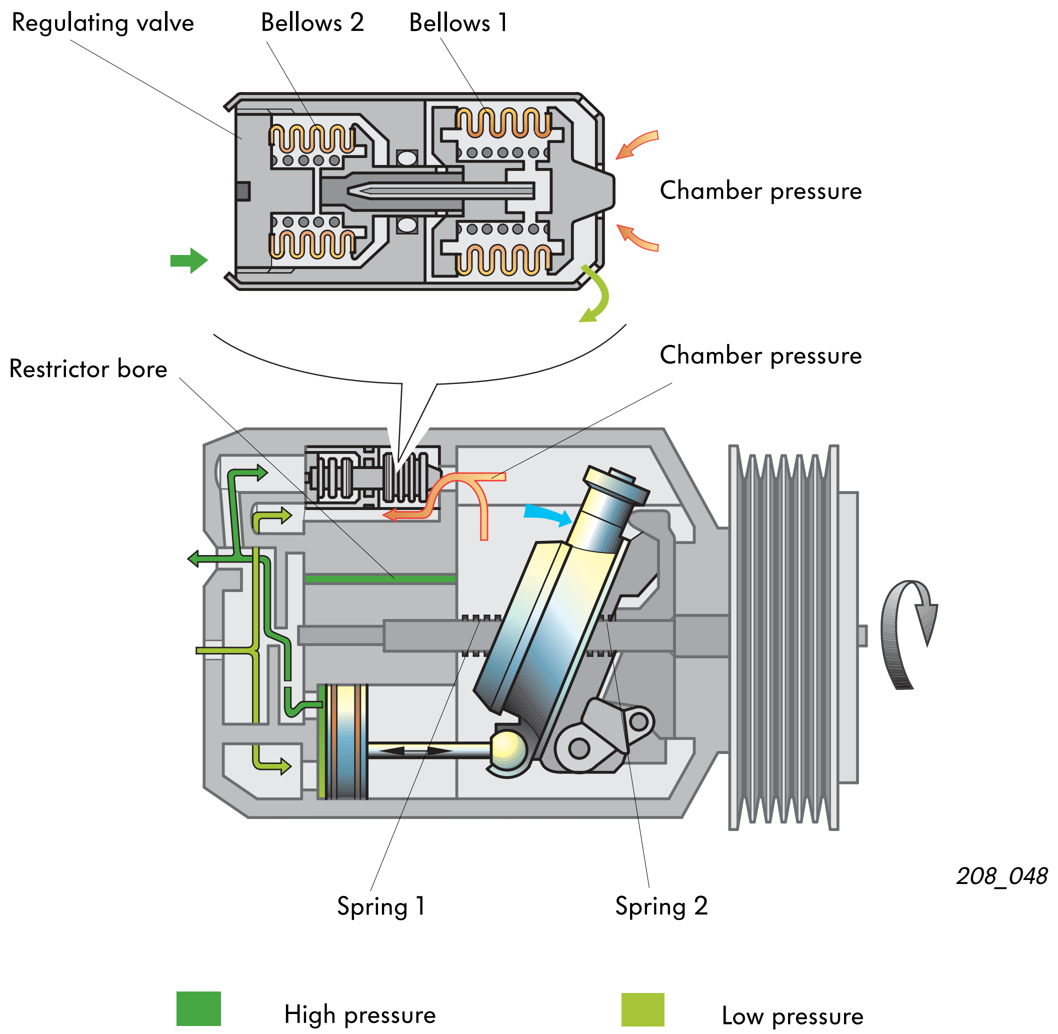
The piston stroke and the delivery rate are defined by the inclination of the wobbleplate.

Inclination – dependent on the chamber pressure and hence the pressure conditions at the base and top of the piston.
The inclination is supported by springs located before and after the wobbleplate.

Chamber pressure – is dependent upon the high and low pressures acting upon the regulating valve and by the calibrated restrictor bore.

High pressure, low pressure and chamber pressure are equal when the air conditioner is off.
The springs before and after the wobbleplate set it to a delivery rate of about 40%.
The advantage of output control is that it eliminates compressor cut-in shock, which often manifests itself in a jolt while driving.

High delivery rate for high cooling capacity - low chamber pressure



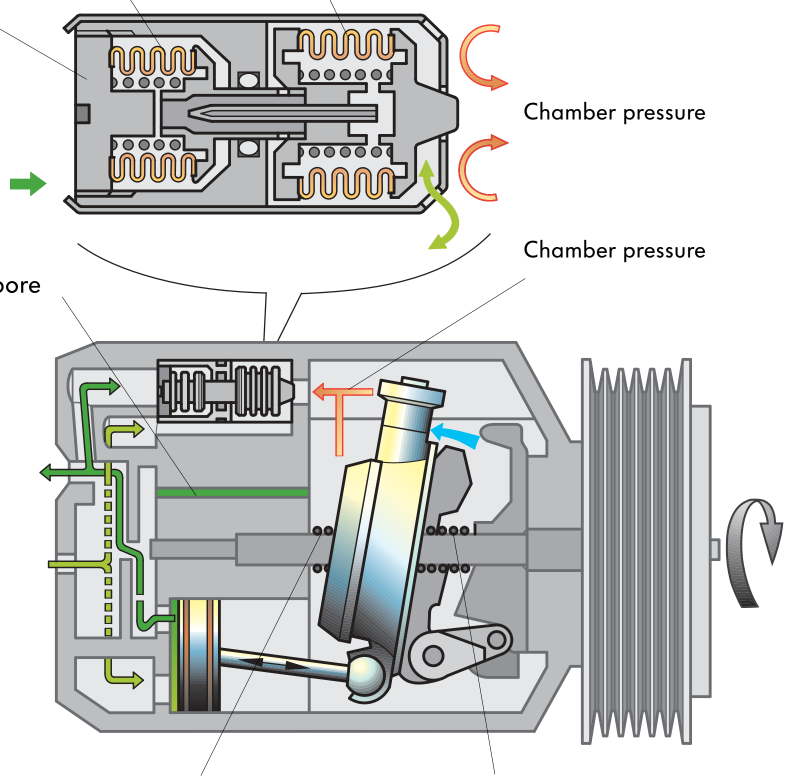
The high and low pressures are relatively high.

- Bellows 2 is compressed by the high pressure .
- Bellows 1 is also compressed by the relatively high low pressure.
- Regulating valve opens. Chamber pressure is reduced via the low-pressure side.
- The combined force resulting from the low pressure acting upon the upper sides of the piston and the force of spring 1 is greater than the combined force resulting from the chamber pressure acting upon the lower sides of the piston and the force of spring 2.

➡ Inclination of wobbleplate increases
= large stroke with high delivery rate

The cooling system

Low delivery rate and low cooling capacity - high chamber pressure



The high and low pressures are relatively low.

– Bellows 2 opens out.

– Bellows 1 also opens out as a result of the relatively low pressure.

– Regulating valve closes.
The low-pressure side is closed against the chamber pressure.

– Chamber pressure rises via the calibrated restrictor bore.

– The combined force resulting from the low pressure acting upon the upper side of the piston and the force of spring is greater than the combined force resulting from the chamber pressure acting upon the lower sides of the piston plus the force of spring 2.

➡ Inclination of wobbleplate decreases
= small stroke with low delivery rate.

Magnetic clutch

The drivetrain is connected between the compressor and vehicle engine while the engine is running by means of the magnetic clutch.

Design

The clutch comprises

- Belt pulley with bearing
- Spring plate with hub
- Magnetic coil

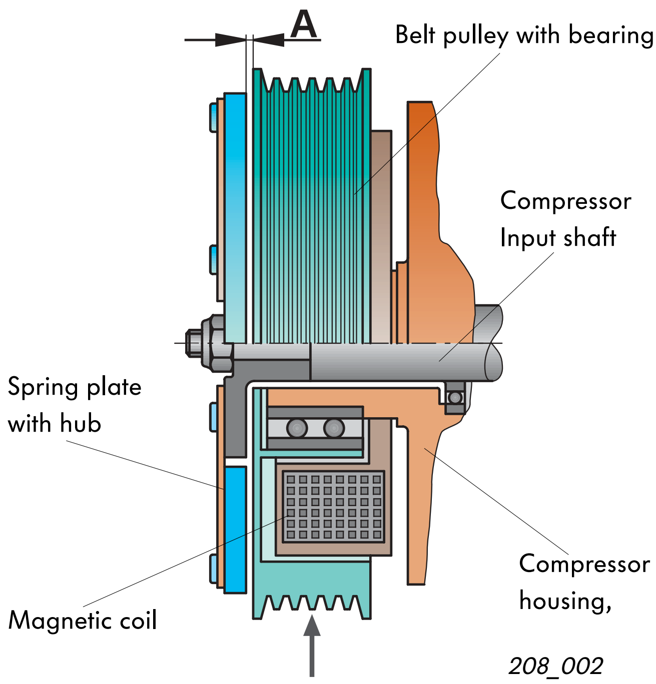
The hub of the spring plate is permanently mounted the compressor input shaft. The belt pulley is mounted in a pivot bearing on the housing of the compressor at the shaft output. The magnetic coil is permanently connected to the compressor housing. There is an open space “A“ between the spring plate and the belt pulley.

Function

The vehicle engine drives the belt pulley (Arrow) by means of the ribbed V-belt.
The belt pulley follows on freely when the compressor is switched off.

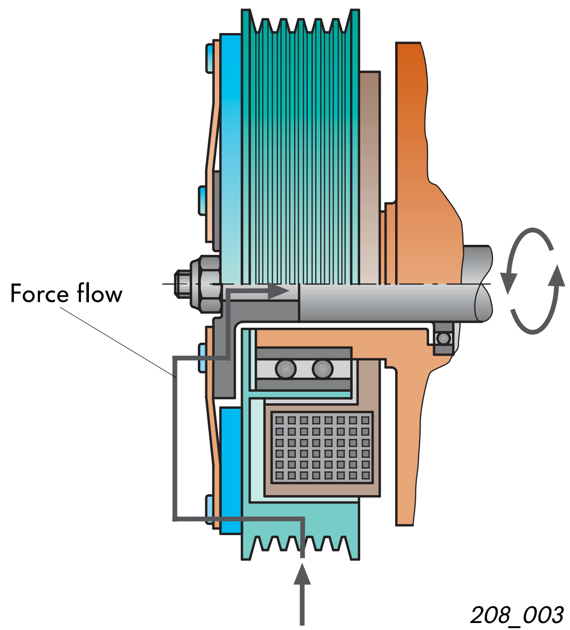
When the compressor is connected, voltage is present at the magnetic coil. A magnetic force field is created. This force field draws the spring plate towards the rotating belt pulley (the open space “A“ is bridged) and makes a positive connection between the belt pulley and the input shaft of the compressor.
The compressor runs on.
The compressor runs on until the electrical circuit to the magnetic coil is opened.
The spring plate is then retracted by the belt pulley by means of springs.
The belt pulley again runs without driving the compressor shaft.

Schematic diagram of clutch switched off



208_002

Schematic diagram of clutch switched on



208_003

For compressor switch-on and switch-off conditions– refer to Air conditioning function control.

The cooling system

The condenser

The condenser is the "cooler" of the air conditioner.

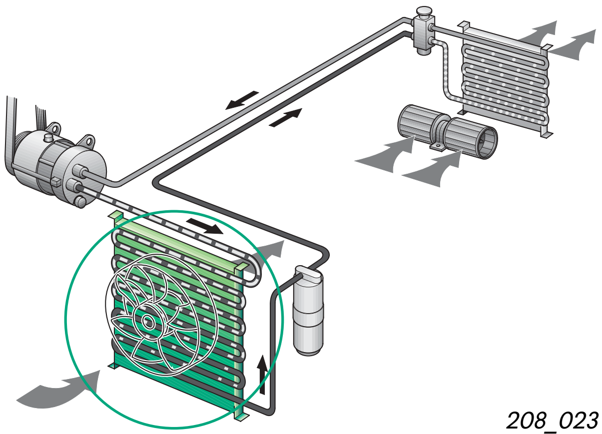
Design of condenser

The condenser comprises a tube coil which is securely attached to fins creating a large cooling surface which facilitates heat transfer.
The condenser cooled by the cooling fan after the air conditioner is switched on in order to ensure that the refrigerant is circulated. The condenser is always installed upstream of the cooler.
This increases the efficiency of the condenser.

Heat is exchanged in the condenser through air cooling. The air is cooled by the headwind and by the cooling fan – an auxiliary fan may still be in use depending on type. The fan usually starts up when the air conditioner is switched on. This is not the case if pressure sender G65 is fitted; in this case, fan switch-on will then be delayed until a specific pressure is reached.
Impurities in the condenser reduce air flow and can also impair condenser capacity and engine cooling.

Function of condenser

Hot, gaseous refrigerant coming from the compressor at a temperature of approx. 50 - 70 °C is injected into the compressor.
The tubes and fins of the condenser absorb heat.
Cool ambient air is ducted over the condenser, absorbing heat in the process and thereby cooling down the refrigerant.
When the refrigerant cools down, it condenses at a specific temperature and pressure and becomes a liquid. At the bottom of the compressor, the refrigerant emerges from the condenser as a liquid.



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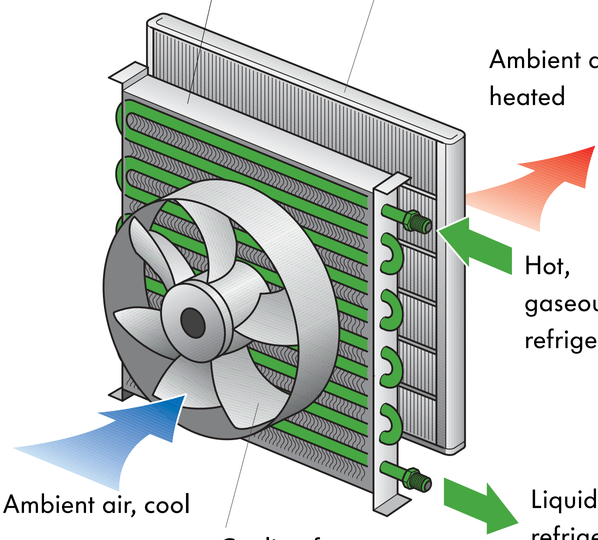
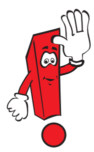


208_024



The condenser is often referred to as "liquefier" in regard to its working method.

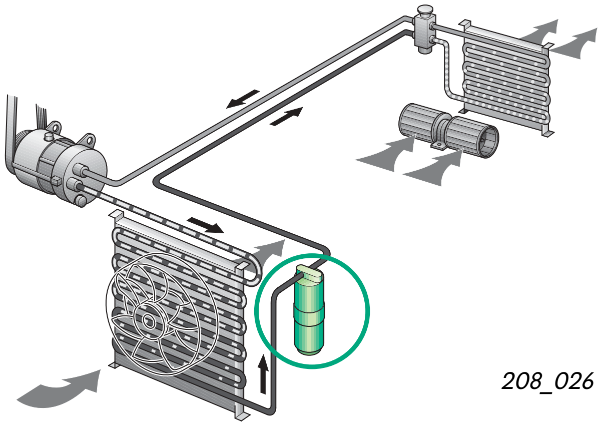
The fluid container and drier

In the refrigerant circuit with expansion valve, the fluid container serves as a refrigerant expansion tank and reservoir.

Different amounts of refrigerant are pumped through the circuit when operating conditions such as the thermal load on the evaporator and condenser and compressor rpm are variable.

The fluid container is integrated in the circuit in order to compensate for these fluctuations.

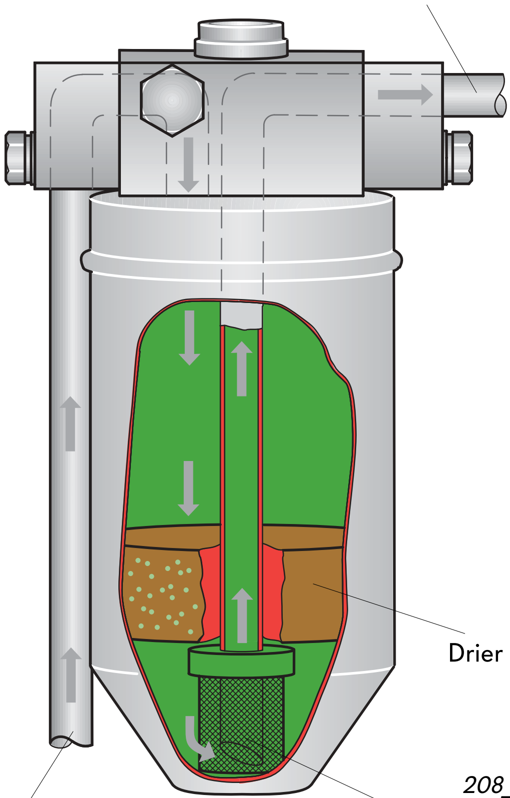
The drier binds chemically moisture which has entered the refrigerant circuit during installation. The drier can absorb between 6 and 12 g of water, depending on type. The amount of water that can be absorbed is temperature-dependent. The amount of water absorbed increases as the temperature drops. Abraded material from the compressor, dirt arising from installation work and similar is also deposited.



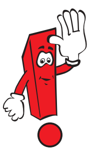
208_026

Function

The liquid refrigerant coming from the condenser enters the container at the side. The refrigerant is collected in the container, then it flows through the drier and along the riser to the expansion valve in an uninterrupted flow containing no bubbles.



208_025



The fluid container is replaced every time the refrigerant circuit is opened. The fluid container must be kept closed as long as possible prior to installation in order to minimise absorption of moisture from the ambient air in the drier.

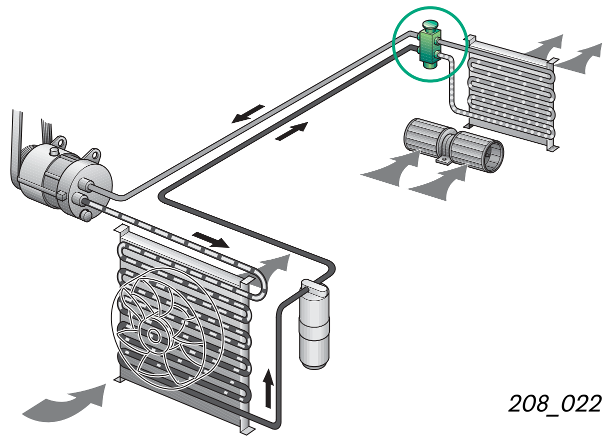
The cooling system

Expansion valve

The expansion valve is the point where the refrigerant in the evaporator expands and cools down. It forms the interface between the high-pressure side and low-pressure side of the refrigerant circuit.

The expansion valve is used to regulate the refrigerant flow to the evaporator – in dependence upon the temperature of the refrigerant vapour at the evaporator outlet.–

No more refrigerant than is necessary to maintain a steady “refrigerating climate“ in the evaporator is expanded in the evaporator.



208_022

The closed control loop

The refrigerant flow is controlled by the expansion valve in dependence upon temperature.

– When the temperature of the refrigerant leaving the evaporator rises, the refrigerant in the thermostat expands. The flow rate of the refrigerant to the evaporator at the globe valve increases.

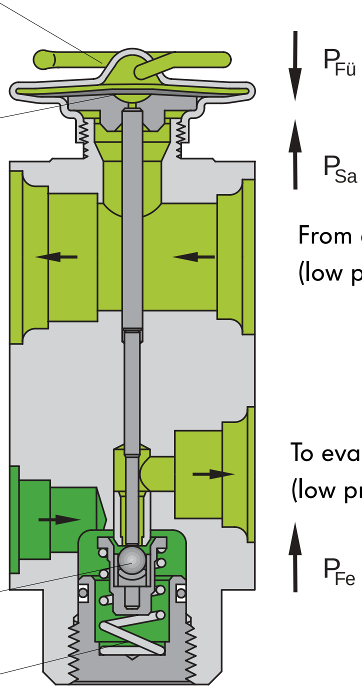
– When the temperature of the refrigerant leaving the evaporator drops, the refrigerant volume in the thermostat decreases. The flow rate to the evaporator at the globe valve is reduced.

There are three forces at play in the thermostatic expansion valve:

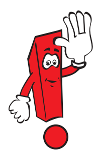
1. The pressure in the sensor line is dependent on the temperature of the superheated refrigerant. This pressures acts upon the membrane as an opening force ($P_{Fü}$).

2. The evaporator pressure (P_{Sa}) acts upon the membrane in the opposite direction.

3. The pressure exerted by the regulating spring (P_{Fe}) acts in the same direction as the evaporator pressure.



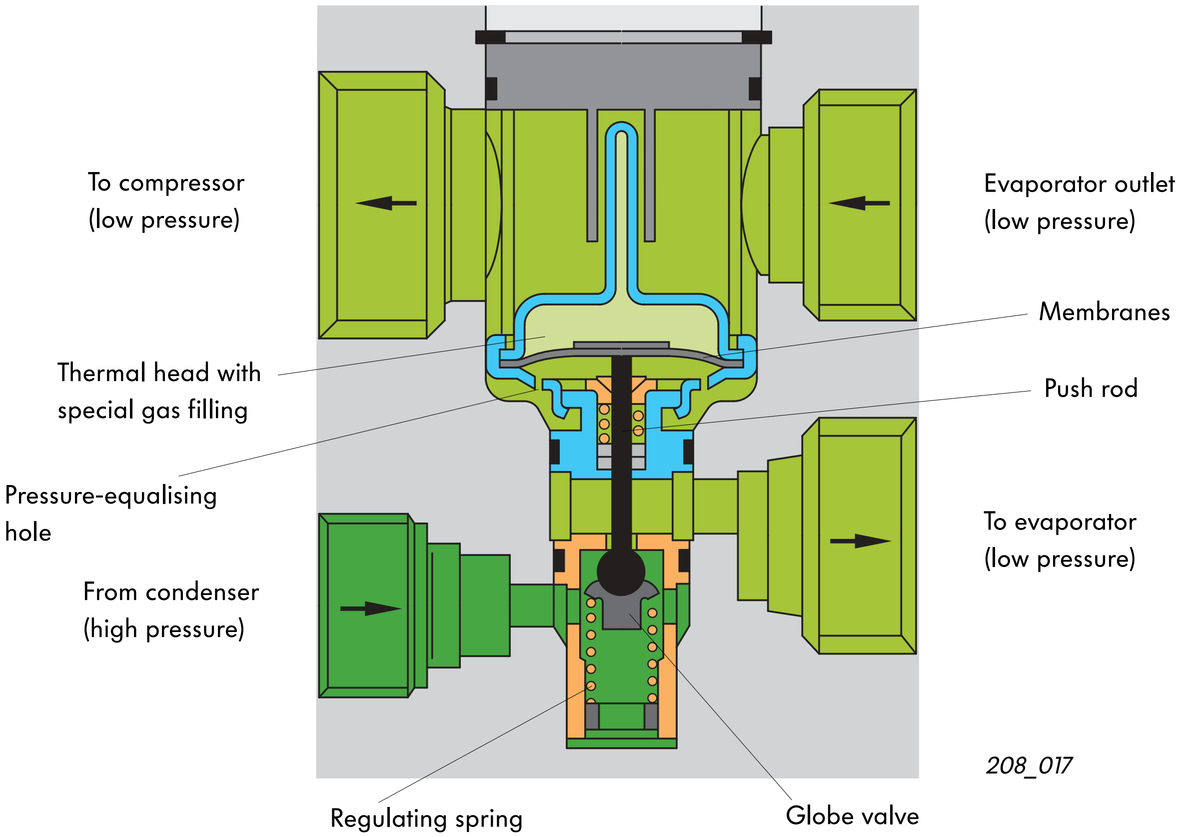
208_015



The expansion valves are set.
Their settings may not be altered.
Do not bend the sensor line, because it is filled with a special gas.

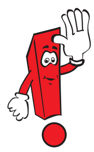
Expansion valve – new generation

This expansion valve is also positioned between the high-pressure side and low-pressure side of the refrigerant circuit directly upstream of the evaporator.



The expansion valve is heat-controlled. It has a control unit with a thermal head and a globe valve.
The thermal head on one side of the membrane has a special gas filling. The other side is connected to the evaporator outlet (low pressure) via pressure-equalising holes.
The globe valve is push rod actuated.
The pressure of the special gas, and therefore also the amount of refrigerant injected, is dependent upon the temperature on the low-pressure side.

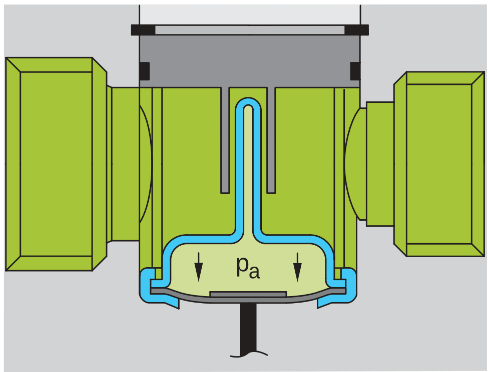
The expansion valve is always fitted with thermal insulation.



Fitting the valve without thermal insulation will alter the set control characteristic.

The cooling system

A increase in cooling load increases the temperature at the evaporator outlet causing
the pressure (p_a) of the gas filling in thermal head to rise

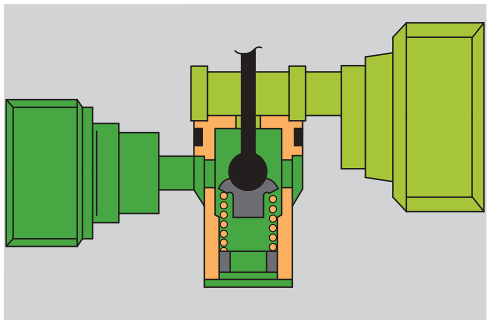


208_018

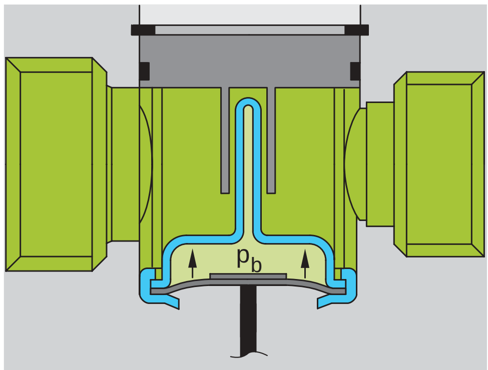
The globe valve cross-section is enlarged
via diaphragms and the push rod.

Refrigerant flows to evaporator and absorbs heat at the transition from high pressure to low pressure

Heat is extracted from the air flowing through the evaporator

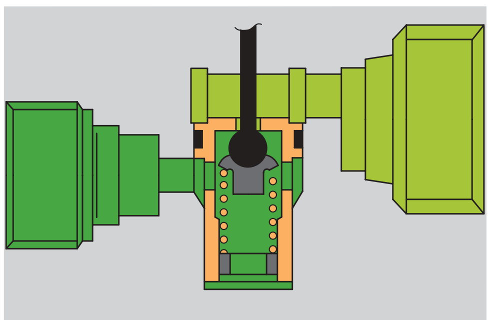

208_019

When the temperature of the refrigerant at the evaporator outlet drops, the
pressure (p_b) in the thermal head drops



208_020

The cross-section of the globe valve, and therefore also the flow rate to evaporator, will again be reduced.

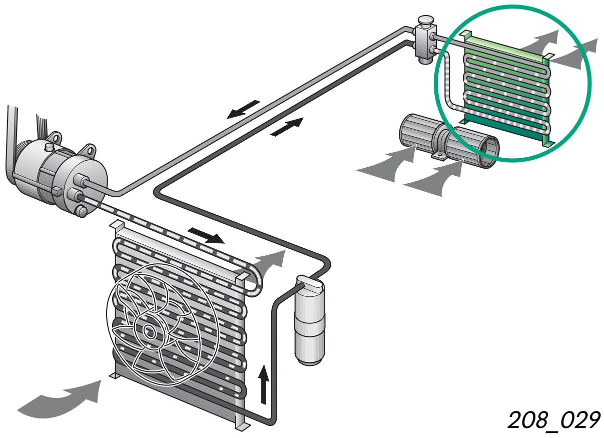

208_021

The valve opening ratio is dependent upon the temperature at the evaporator outlet (low pressure).
Pressure equalisation is controlled.

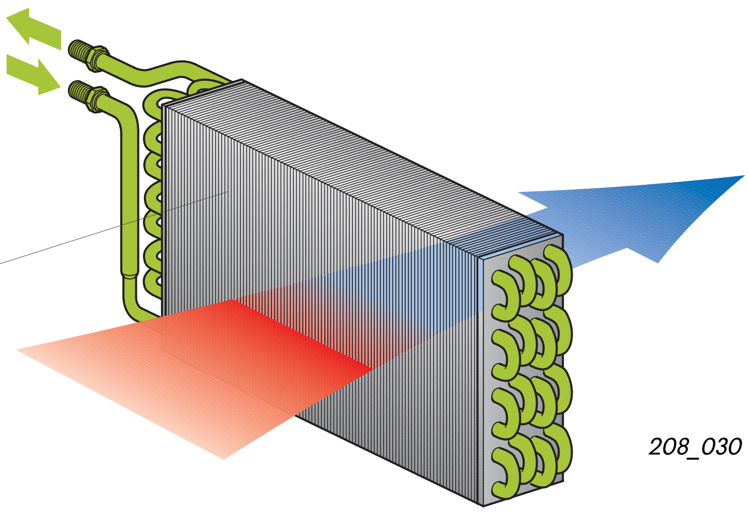
The evaporator

The evaporator operates according to the same principle as a heat exchanger.

It is an integral part of the air conditioner in the heater box. When the air conditioner is switched on, heat is extracted from the air which flows through the fins of the cold evaporator. This air is cooled, dried and cleaned in the process.



208_029



208_030

Function

The refrigerant released by the expansion valve expands in the evaporator, cooling the evaporator down considerably.

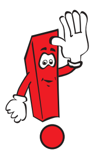
The refrigerant becomes a gas (boiling point).

When the refrigerant in the evaporator boils, the temperatures are well below the freezing point of water.

The refrigerant extracts the heat required for evaporation from its surroundings – which is the air flowing through the evaporator in this case.

This air is channeled into the passenger cabin in a “cooled" state.

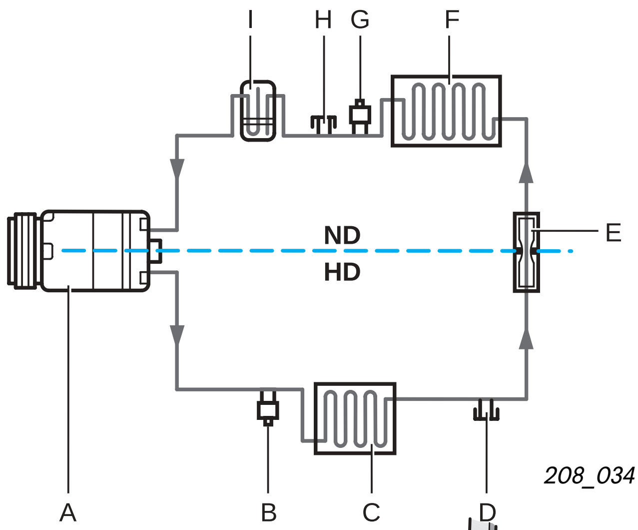
Moisture in the cooled air collects at the evaporator in the places where the air temperature drops below the dewpoint temperature, i.e. it condenses. Condensation water is produced.
The air is “dried“.
This improves the climate and air quality inside the vehicle noticeably.
Deposits of matter suspended in the air build up at the evaporator in addition to moisture.
The evaporator also "purifies" the air.



Pools of water below a stationary vehicle (condensation) are therefore not an indication of a fault.

The cooling system

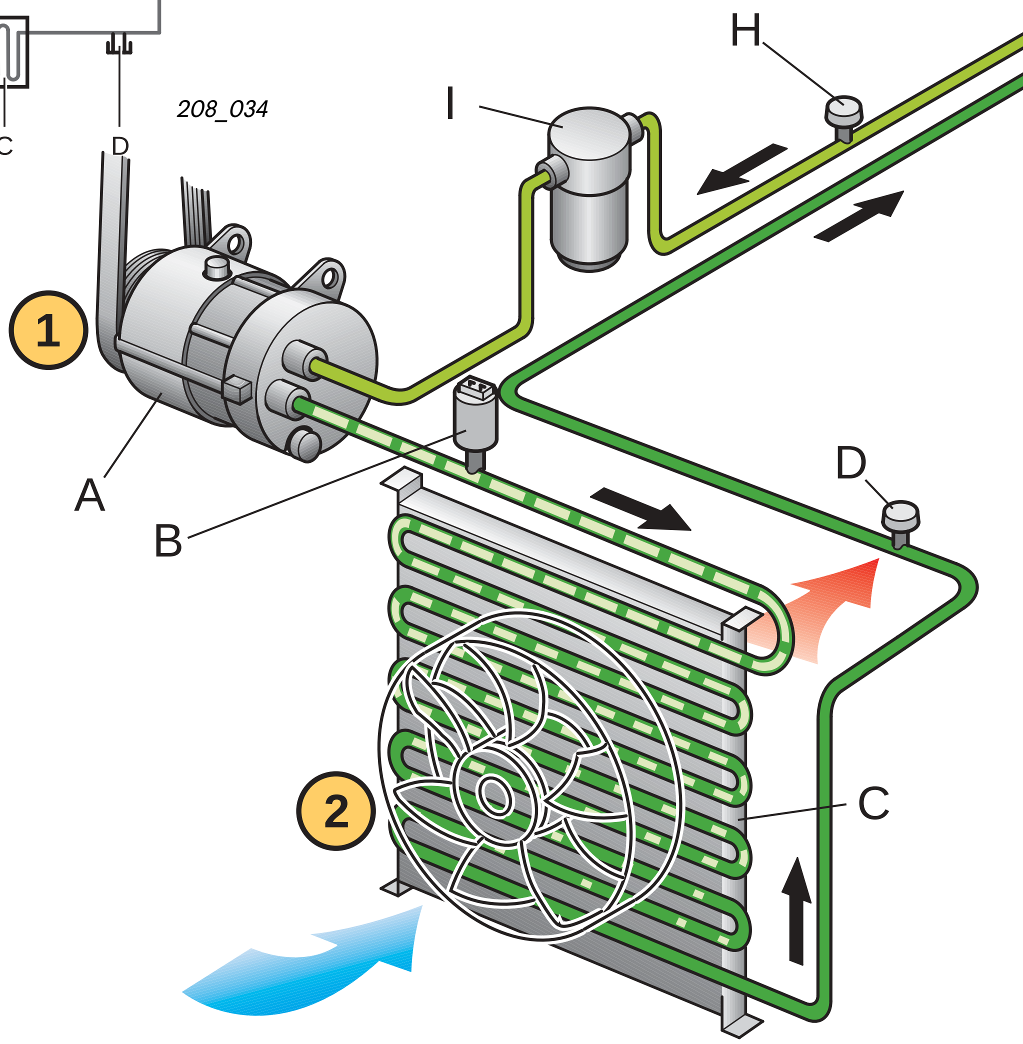
Refrigerant circuit with restrictor

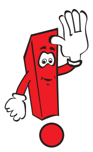


Working pressure HD = high pressure
ND = low pressure

Schematic diagram of a refrigerant circuit with restrictor

208_034





1 MPa = 10 bar

Pressures and temperatures in the circuit

Compression ratio
Max. pressure 2 MPa (20 bar)
Max. temperature 70 °C

Condensation
Max. pressure 2 MPa (20 bar)
Temperature reduction: approx. 10 °C

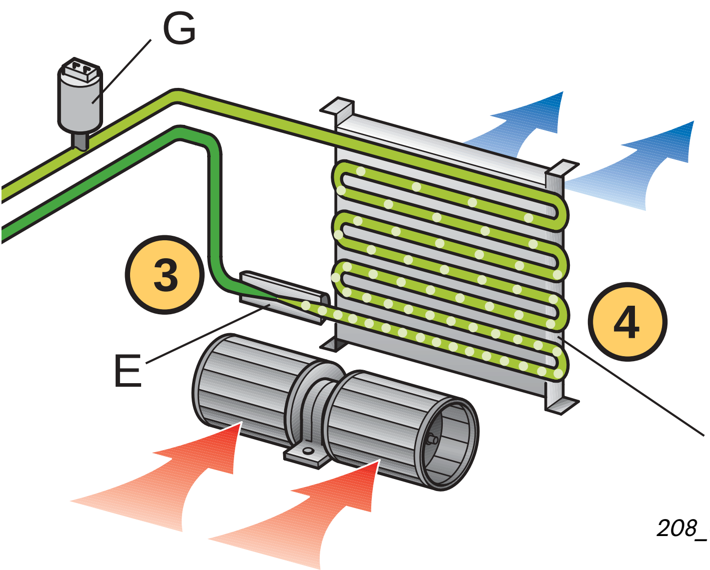
Legend

High pressure

Low pressure

The component parts:

A Compressor with magnetic clutch
B Low-pressure switch
C Condenser
D High pressure service connection
E Restrictor
F Evaporator
G Low-pressure switch
H Low-pressure service connection
I Collecting tank



208_007

In contrast to the circuit with expansion valve, the liquid refrigerant is injected into the evaporator through a restrictor.

In restrictor-regulated air conditioners, a collecting tank is fitted at the low-pressure side in place of the fluid container on the high-pressure side.

This collecting tank serves as a reservoir and protects the compressor (fluid shock). Also refer to page 31.

All other components are identical to those used in the circuit with expansion valve.

Additional connections for service work or sensors for monitoring functions can be integrated in the circuit, depending on circuit design and necessity.

The pressures and temperatures are dependent upon the momentary operating state of the refrigerant circuit. The specified values are achieved after a specific period depending on the ambient temperature (refer to Workshop Manual).

208_033

Expansion
from 2 MPa (20 bar) to > 0.15 MPa (1.5 bar)
Temperature: from 60 °C to > –4 °C

Evaporation
Max. pressure > 0.15 MPa (1.5 bar)
Temperature: > –4 °C

The cooling system

The restrictor

The restrictor is a narrowing in the refrigerant circuit located directly upstream of the evaporator. This narrowing “restricts“ the flow of the refrigerant.

The refrigerant is warm under high pressure upstream of the restrictor.

The pressure of the refrigerant drops rapidily when it passes the restrictor.

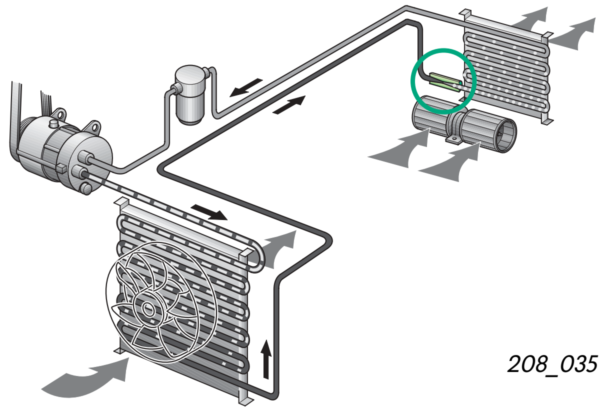
The refrigerant is cold at low pressure.

The restrictor is therefore the “interface“ between the high-pressure and low-pressure sides of the refrigerant circuit. A seal ensures that the refrigerant only passes the restrictor at the narrowing.

Tasks

- To determine the flow rate of the refrigerant by means of a calibrated bore. The amount of refrigerant which can flow through this bore is limited by the pressure in the refrigerant circuit.
- To maintain the pressure on the high-pressure side of the refrigerant circuit and keep the refrigerant in a liquid state when the compressor is running.
- The pressure in the restrictor drops. The refrigerant cools down before it enters the evaporator through partial evaporation.
- Atomisation of the refrigerant.

The restrictor has a dirt strainer upstream of the narrowing.
A strainer for atomising the refrigerant before it reaches the evaporator is located downstream the narrowing.



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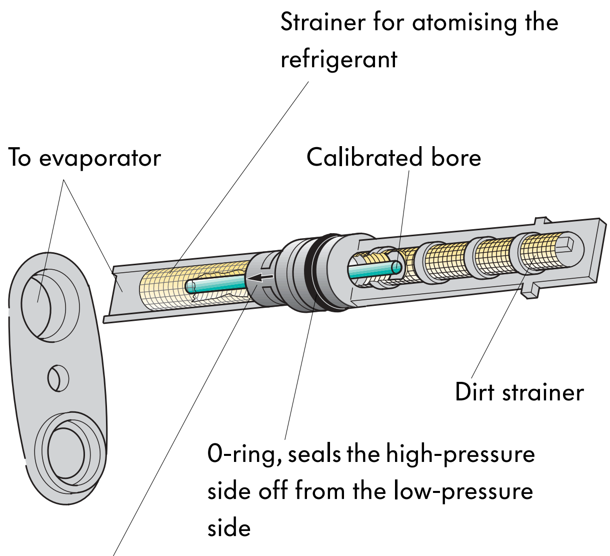


208_016

Please note the installation position!
The arrow on the restrictor points to the evaporator.

The collecting tank

There is a collecting tank in the low-pressure part of air conditioners with restrictor. This tank is installed in a warm location in the engine compartment (post-evaporation).

It serves as an equalising vessel and reservoir for the refrigerant and refrigerant oil and also protects the compressor.

The gaseous refrigerant coming from the evaporator enters the tank. If there are traces of moisture in the refrigerant, they are bound in the integrated drier.

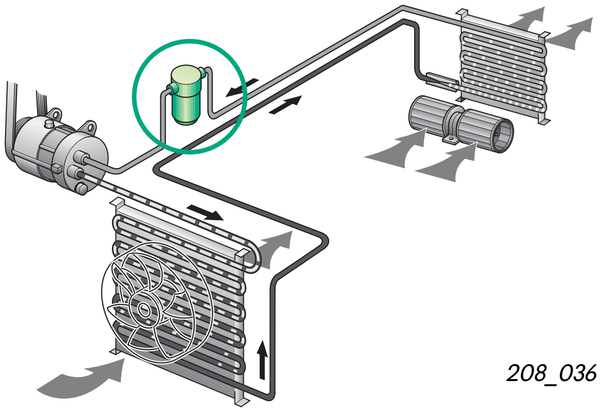
The refrigerant collects in the upper part of the plastic cap and is certain to be in a gaseous state when it is drawn in by the compressor through the U-tube.

As a result, the compressor draws in gaseous refrigerant only, and no liquid droplets. Protection of the compressor against damage is thereby ensured.

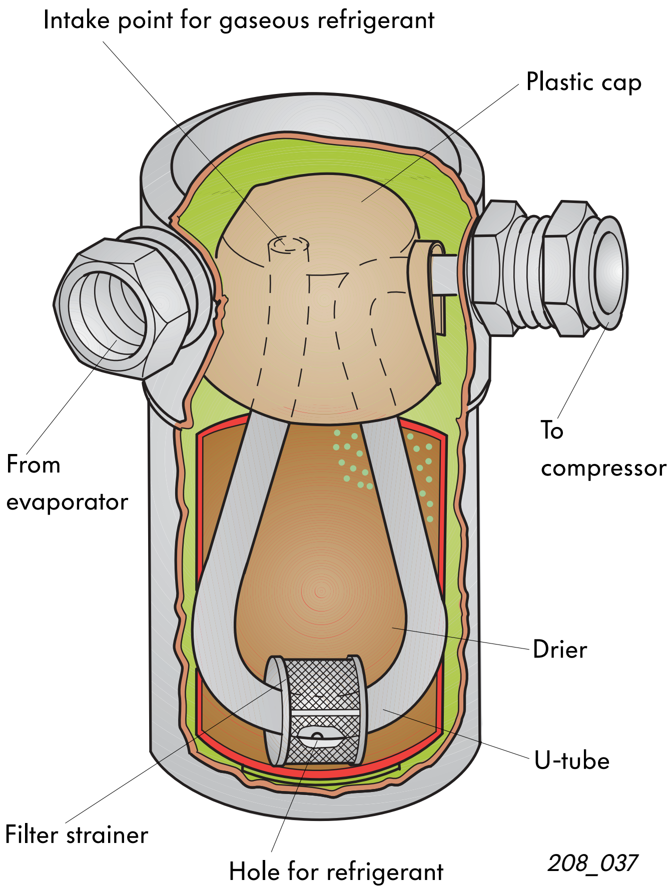
The refrigerant collects at the base of the collecting tank.

The refrigerant drawn in by the compressor absorbs refrigerant through a hole in the U-tube.

A filter strainer prevents the ingress of impure refrigerant through this hole.



208_036



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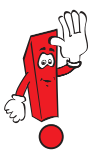
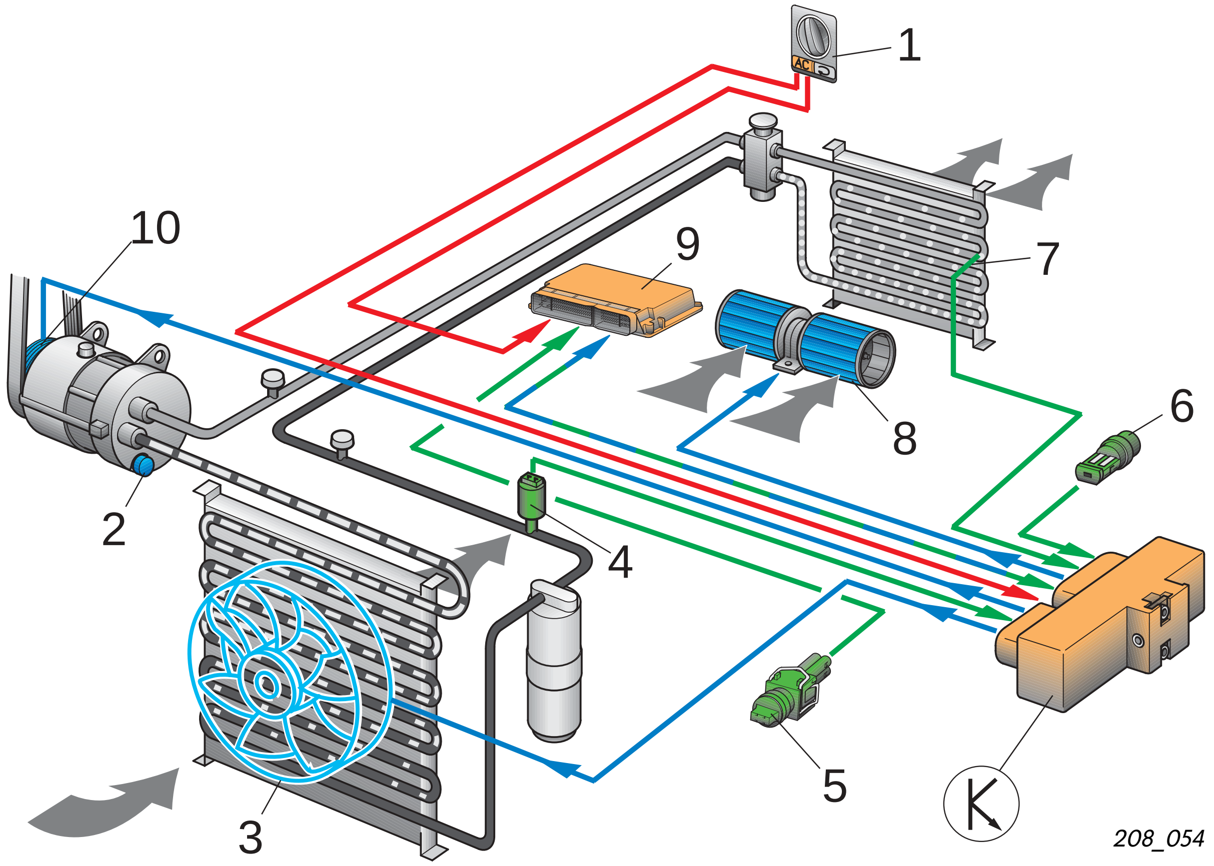


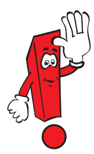
The collecting tank must be kept closed as long as possible prior to installation (leave the sealing plugs on the connections) in order to minimise moisture absorption from the ambient air in the drier.

System control



An air conditioner will only function if all system components are working properly. Failure of one of these components could cause the working pressures to change. In this case, it is not possible to rule out consequential damage to the system and the engine. To avoid this, there are monitoring devices in the refrigerant circuit.

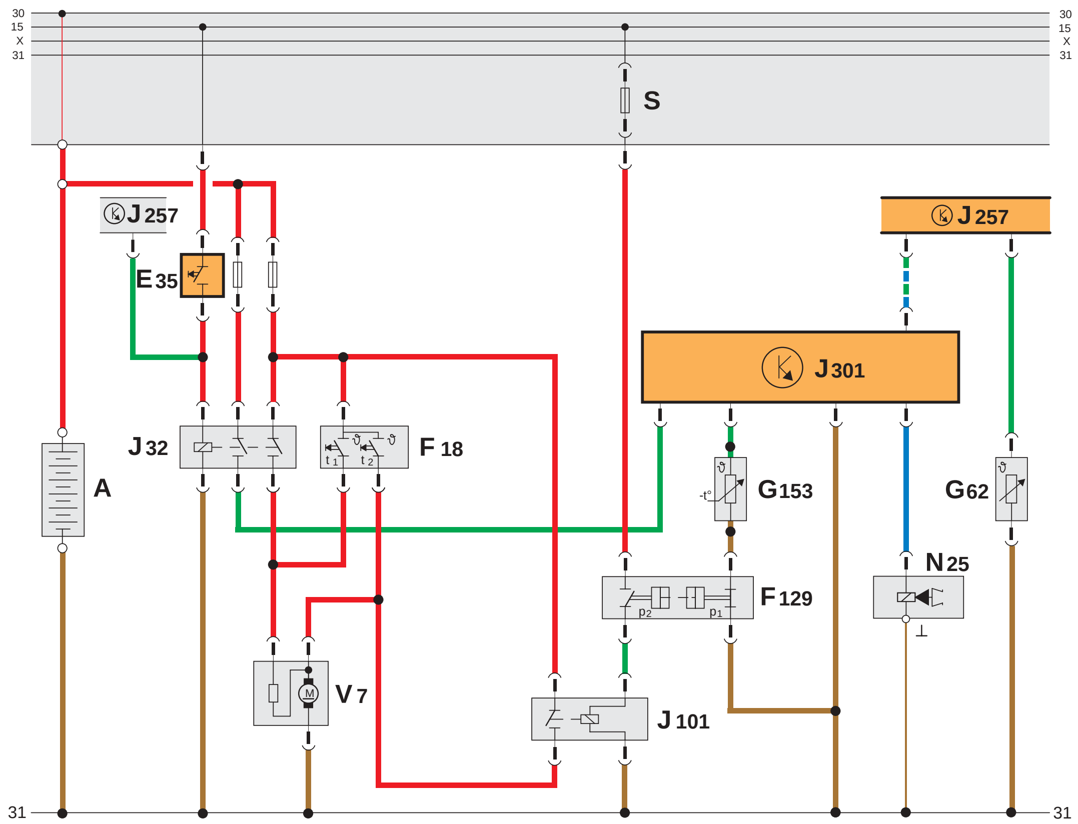
A control unit processes the signals from the monitoring devices and controls the periodic switch-off and switch-on of the compressor and the speed of the fan. This ensures that the pressure level in the refrigerant circuit always adapts itself to the normal values.
In systems equipped with an open-loop compressor, the signals from the monitoring device are also used for adaptation to demand for cooling.
(switch-on and switch-off the air conditioner in accordance with demand for refrigeration.
Icing of the evaporator is avoided at the same time.)
The diagram shows the basic layout of the air conditioner.



The air conditioner does not necessarily have to have all the components shown in the diagram. Neither do these components have to be connected in this way.
The diagram shows the system control of a simple manual air conditioner.

1 Air conditioner switch
2 Pressure relief valve at compressor
3 Radiator fan
4 Air conditioner pressure switch
5 Coolant temperature sender
6 Radiator fan thermo switch
7 Evaporator temperature sender
8 Fresh air blower
9 Engine control unit
10 Magnetic clutch

(K) Air conditioner control unit (and/or radiator fan control unit, depending on system type)

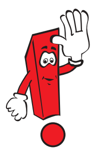


208_055

A Battery
E35 Air conditioner switch
F18 Radiator fan thermo switch
t_1 = 95 °C
t_2 = 103 °C
F129 Pressure switch for air conditioner
P_1 = 0.2 MPa (2 bar)/3.2 MPa (32 bar)
P_2 = 1.6 MPa (16 bar)
G62 Coolant temperature sender
G153 Evaporator temperature sender
J32 Air conditioner relay
J101 Radiator fan 2nd speed relay
J257 Mono-Motronic control unit
J301 Air conditioner control unit
N25 Air conditioner magnetic clutch
V7 Radiator fan
S Fuse

Simple functional example showing how the compressor (via magnetic clutch N25) and radiator fan are switched on and off.

Colour codes:
Positive
Negative
Input signal
Output signal
Bidirectional signal

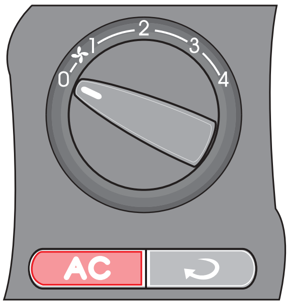


In the new-generation air conditioners, there is a high pressure sender in place of the pressure switch for air conditioner (refer to page 36).

System control

Components of the safety systems

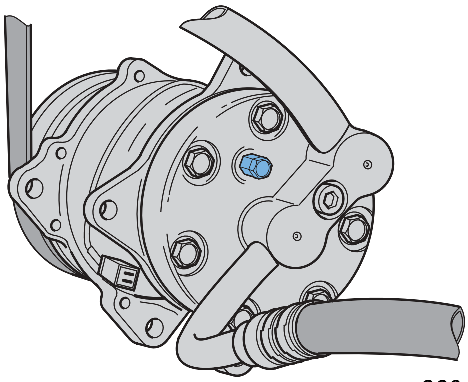
Air conditioner switch E35



208_068

Switch for switching on the air conditioner – the magnetic clutch makes the connection to the compressor.
In automatically controlled systems, the radiator fan and the fresh air blower start simultaneously.
In manual air conditioners, the fresh air blower must be switched to the 1st speed.
A signal indicating that the air conditioner has been switched on is transmitted to the engine control unit, and engine idling speed is increased (to compensate for load resulting from compressor work).
The switch may be located downstream of an ambient temperature switch.
This ensures that the air conditioner cannot start when the temperature is below 5 °C.

Pressure relief valve

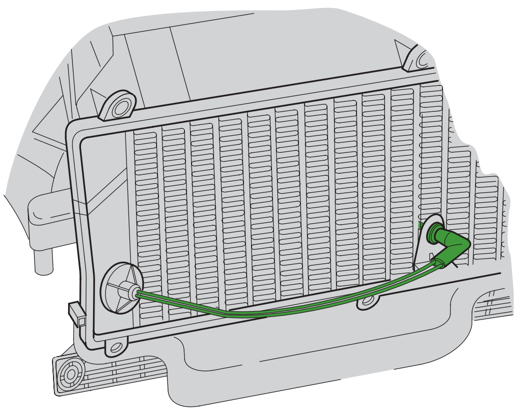


208_056

The valve (previously: bursting seal) is attached directly to the compressor or fluid container. The valve opens at a pressure of approx. 3.8 MPa (38 bar) and closes when the pressure drops (approx. 3.0 - 3.5 MPa/30 - 35 bar).
Depending on type, a plastic disc which ruptures as soon as the valve lifts can be attached.

In this case, the cause of the excess pressure in the system must be determined.
The bursting seal should only be replaced when the system is empty.

Evaporator temperature sender G153



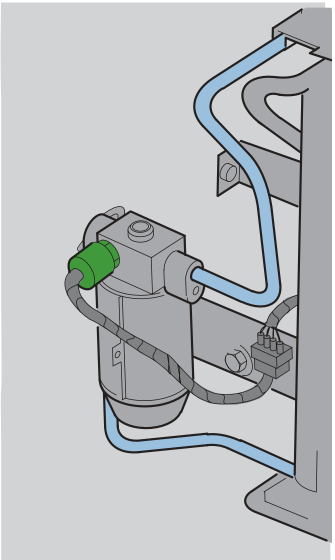
208_061

The evaporator temperature sender measures the temperature between the cooling fins of the evaporator. The sender signal is transmitted to the air conditioner control unit. When the evaporator temperature drops too low, the compressor is switched off.
The compressor is switched off at approx. –1 °C to 0 °C and switched on at approx. +3 °C
Icing of the evaporator by freezing condensation water is prevented.

In some systems, evaporator temperature switch E33 is used in place of this sender. The power supply to the magnetic clutch is opened directly by means of this switch.

Other systems control this function by means of an ambient temperature switch.

Pressure switch F129



208_057

To monitor and/or limit the pressure conditions in the closed refrigerant circuit, high-pressure and low-pressure switches are installed on the high pressure side.

If unacceptable pressures build up inside the system, the compressor will be switched off via the magnetic clutch.

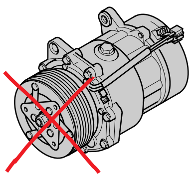
The pressure switch can be directly integrated in the line or attached to the fluid container.

Pressure switch F129 is a 3-way combination switch for:

- safeguarding the cooling air flow (fan circuit)
- safeguarding the pressure conditions.

The pressure switch operates in the following conditions:

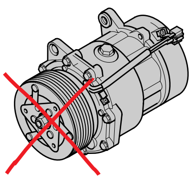
$p > 3{,}2$ MPa =



208_058

- it switches off the magnetic clutch via the air conditioner control unit at an excess pressure of approx. 2.4 to 3.2 MPa (24 to 32 bar). This excess pressure can be caused by a dirty condenser, for example.

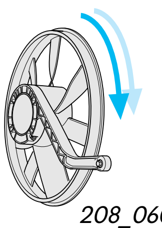
$p < 0{,}2$ MPa =



208_059

- it switches off the magnetic clutch via the air conditioner control unit when the pressure drops below a minimum value (0.2 MPa/ 2bar) . This can be caused by loss of refrigerant, for example.

$p > 1{,}6$ MPa =

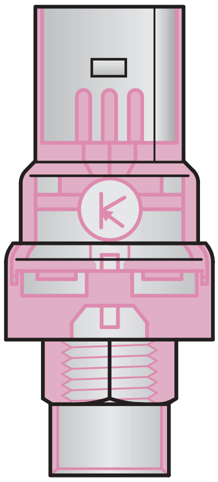


208_060

- it switches the fan one speed higher at 1.6 MPa (16 bar) excess pressure. As a result, condenser performance is optimised.

System control

High pressure sender G65



208_062

- A new generation of senders for monitoring the refrigerant circuit.
- Air conditioner pressure switch F129 has been replaced by an electronic pressure sensor. The evaluation electronics in the air conditioner and engine control units have been adapted accordingly.
- Like pressure switch F129, the high pressure sender is integrated in the high pressure line.

It registers the refrigerant pressure and converts the physical quantity of pressure to an electrical signal.
Unlike the air conditioner pressure switch, the sender registers not only the defined pressure thresholds, it also monitors the refrigerant pressure throughout the working cycle.

Signal utilisation
in the engine control unit
in the radiator fan control unit

These signals indicate the load being exerted on the engine by the air conditioner and the pressure conditions in the refrigerant circuit. The next higher stage of the cooling fan and the magnetic clutch of the compressor are activated and deactivated via the radiator fan control unit.

Substitute function

If the radiator fan control unit fails to detect any signals, then the compressor will be switched off for safety reasons.

Advantages

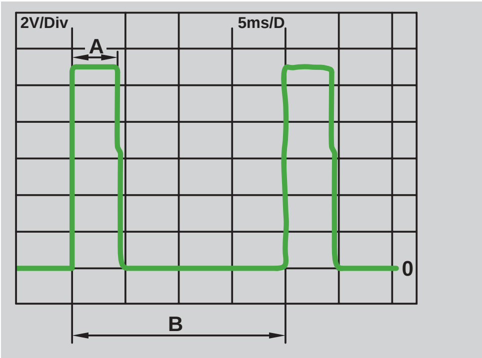
- The idling speed of the engine can be adapted exactly to the power consumption of a specific compressor.
- The radiator fan speed activation and deactivation cycles are staggered with a short time delay.
  As a result, changes in the speed of the cooling fan are barely perceptible at idling speed. This enhances comfort especially in vehicles with engines with low power outputs.

Self-diagnosis “fault message“

The fault in the high pressure sender is stored to the fault memory of the **engine electronics** .

e.g.: 00819 high pressure sender G65
“Signal too low“

Function of high pressure sender



208_109

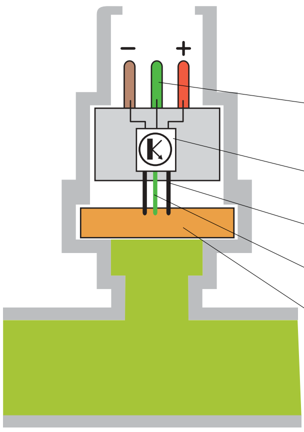
The refrigerant pressure is applied to a silicon crystal. Depending on the pressure level, the crystal will be more or less “deformed“.

The silicon crystal, together with a microprocessor, is integrated in the sensor and supplied with voltage.

One of the properties of the silicon crystal is that its electrical resistance changes when it is deformed. Depending on the pressure characteristic, a test voltage picked off at the silicon crystal also changes as a result.

The test voltage is conducted to the microprocessor and converted to a pulse-width modulated signal (A = pulse width, B = signal distance).

At low pressure

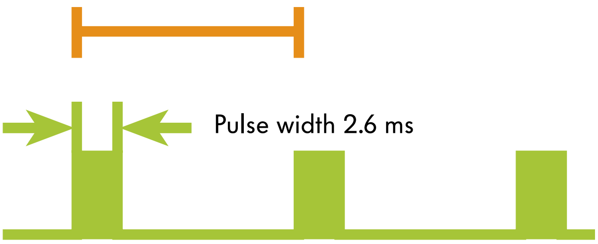


208_063

At a low pressure, the crystal undergoes minimal “deformation".
The voltage applied is therefore only opposed to a low electrical resistance.

The voltage change is small.

Pulse width signal



208_064

The microprocessor of the high pressure sender outputs a small pulse width at low pressures.

Pulse width signals are generated at a frequency of 50 Hz per second.
This is equivalent to a period duration of 20 ms = 100%.

At a low pressure of 0.14 MPa (1.4 bar), the pulse width is 2.6 ms.
This is equivalent to 13% of the period duration.